APR 3 1925

Engineering Library


# ENGINEERING:

## An Illustrated Weekly Journal.

OFFICES FOR ADVERTISEMENTS AND PUBLICATION, 35 & 36, BEDFORD STREET, STRAND, LONDON, W.C.2.

VOL. CXIX.—No. 3090.] *LONDON: FRIDAY, MARCH 20, 1925.* [*Registered at the General Post Office as a Newspaper.*] [PRICE ... 1s. BY INLAND POST 1s. 2½d.



**Aveling & Porter, Ltd.,**
ROCHESTER.
Steam & Crude Oil Road Rollers, &c. 2581

**A. G. Mumford, Ltd.,**
CULVER STREET WORKS, COLCHESTER.
ON ADMIRALTY AND WAR OFFICE LISTS.
ENGINES for Torpedo Boats, Yachts, Launches.
BOILER FEED PUMPS.
See advertisement page 15.
PATENT WATER-TUBE BOILERS.
AUTOMATIC FEED REGULATORS.
And Auxiliary Machinery as supplied to the Admiralty. 2179

**Dredging Plant**
OF ALL DESCRIPTIONS.
FLOATING CRANES. COAL BUNKERING VESSELS.
Werf Conrad, HAARLEM, HOLLAND.
Agents: MARINE WORKS, LTD., FRIARS HOUSE, 39-41, NEW BROAD ST., LONDON, E.C.2.
*See half-page Advert. last week and next week.* 2087

**CRANES. All Types.**
GEORGE RUSSELL & CO., LTD., Motherwell. 2591

STEEL TANKS, PIPES, GASHOLDERS, &c.
**Thos. Piggott & Co., Limited,**
BIRMINGHAM. 2530
See Advertisement last week, page 13.

**Spencer-Hopwood & Kirke**
PATENT BOILERS *See Page* 38. *March* 13. 1994
Sole Makers: SPENCER-BONECOURT, LTD., Parliament Mansions, Victoria St., London, S.W.

**Tank Locomotives.**
Specification and Workmanship equal to Main Line Locomotives.
R. & W. HAWTHORN, LESLIE & CO. LTD., ENGINEERS, NEWCASTLE-ON-TYNE. 2572

**Brett's Patent Lifter Co.**
LIMITED.
Hammers, Presses, Furnaces,
COVENTRY. 616

**Invincible Gauge Glasses.**
*BUTTERWORTH BROS., Ltd.,*
*Newton Heath Glass Works,*
*Manchester.* Od 9753

**For Your Repairs or any**
SPECIAL MACHINERY, try
THOMAS HUNT & SONS,
Albion Ironworks,
Bridge Road West, Battersea, S.W.11.
Est. 1854. 2703

**P. & W. MacLellan, Ltd.,**
CLUTHA WORKS, GLASGOW.
MANUFACTURERS OF
RAILWAY CARRIAGES AND WAGONS
OF EVERY DESCRIPTION.
RAILWAY IRONWORK, BRIDGES, ROOFING, &c
Chief Offices: 129, Trongate, Glasgow. Od 8547
Registered Offices: Clutha House, 10, Princes St., Westminster, S.W.1.

**Fuller, Horsey, Sons & Cassell,**
SPECIALISTS
in the
SALE AND VALUATION
of 1834
PLANT AND MACHINERY
and
ENGINEERING WORKS,
11, BILLITER SQUARE, E.C.3.

Iron and Steel
**Tubes and Fittings.**
Sole Licensees in Great Britain for the manufacture of "Armco" Rust and Corrosion Resisting Iron Tubes. 2267
**The Scottish Tube Co., Ltd.**
HEAD OFFICE: 34, Robertson Street, Glasgow.
See Advertisement, page 33, March 13.

**YARROW & CO. (1922), LTD., GLASGOW.**
PASSENGER AND CARGO STEAMERS.
SHALLOW DRAFT VESSELS. 2276

**Campbells & Hunter, Ltd.**
Gear Cutting.
Worm Wheels cut up to 13 ft. diam.
Bevel and Mitre Wheels planed up to 6 ft. 6 in. diam.
Spur Wheels cut up to 12 ft. 6 in. diam.
DOLPHIN FOUNDRY, LEEDS. 4547

**VOSPER & Co., LTD.,**
PORTSMOUTH,
SHIP & LAUNCH BUILDERS, Od 3551
ENGINEERS & BOILER MAKERS.
THE GLASGOW ROLLING STOCK AND PLANT WORKS.
**Hurst, Nelson & Co., Ltd.,**
Builders of RAILWAY CARRIAGES, WAGONS ELECTRIC CARS, and EVERY OTHER DESCRIPTION OF RAILWAY and TRAMWAY ROLLING STOCK.
Makers of WHEELS and AXLES, RAILWAY PLANT, FORGINGS SMITH WORK, IRON & BRASS CASTINGS.
PRESSED STEEL WORK OF ALL KINDS. Od3382
Reg. Office and Chief Works: Motherwell. London Office: 32, Great St. Helen's, Bishopsgate, E.C.3.

**OIL FUEL APPLIANCES,**
*Systems*
PRESSURE AIR, STEAM
*For Boilers of all types.*
KERMODES LIMITED,
35, The Temple, Dale Street, Liverpool.
*Naval Outfits a Speciality,*
also for Merchant Ships, for Factories, Locomotives, and Industrial Process Furnaces of all kinds.
Supplied to the British and other Governments.
Telephone No.: Central 2832.
Telegrams: "Warmth." 4078

**Gearing of all Descriptions.**
GEAR WHEELS up to 10 ft. diameter.
FLY ROPE and SPUR DRIVING WHEELS up to 28 ft. diameter.
BRICK and CLAYWORKING MACHINERY of all kinds.
ENGINES:—"Uniflow," "Corliss," or Drop Valve.
CLAYTON, GOODFELLOW & CO., LTD. Blackburn. 2653

RAILWAY AND TRAMWAY ROLLING STOCK.
**Hurst, Nelson & Co., Ltd.,**
THE GLASGOW ROLLING STOCK AND PLANT WORKS, MOTHERWELL. Od 3382

**E. J. Davis, M.I.Mech.E.,**
Gas Engines Inspected, Tested and Reported upon. Over 25 years' experience. Tel.: Maryland 1736 & 1737. Wire: "Rapidising London." —Great Eastern Road, Stratford, E. 15. 1794

**The Glasgow Railway Engineering Company,**
GOVAN, GLASGOW. LTD.,
London Office—12, Victoria Street, S.W.
MANUFACTURERS OF
RAILWAY CARRIAGE, WAGON & TRAMWAY WHEELS & AXLES.
CARRIAGE & WAGON IRONWORK, also CAST-STEEL AXLE BOXES. 2633

**PROPELLERS**
AND PROPULSION PROBLEMS.
Special designs only.
"Circulation Theory."

**Akimoff Propeller Company,**
PHILADELPHIA, U.S.A. 2349

**Belliss Three-crank Compound**
ENGINES, 800 Kw., Dynamos 230 Volt D.C. Brush, Parsons 600 Kw., EXHAUST TURBINE SET 220 Volt, D.C., with complete condensing plant. Very low price.
JENNINGS, 2402
West Walls,
Newcastle-on-Tyne.

**John Bellamy Limited**
MILLWALL, LONDON, E.
GENERAL CONSTRUCTIONAL ENGINEERS. 1216
**Boilers, Tanks & Mooring Buoys**
STILLS, PETROL TANKS, AIR RECEIVERS, STEEL CHIMNEYS, RIVETTED STEAM and VENTILATING PIPES, HOPPERS, SPECIAL WORK, REPAIRS OF ALL KINDS.

IRON & STEEL
**Tubes and Fittings**
AND
**Steel Plates.**
**Stewarts and Lloyds, Ltd.**
GLASGOW BIRMINGHAM LONDON.
See Advertisement, page 55. 2584

**Peter Brotherhood Ltd.,**
PETERBOROUGH.
STEAM ENGINES AND TURBINES.
GAS AND OIL ENGINES.
AIR COMPRESSORS.
REFRIGERATING PLANT. 1475
See Advertisement, page 51, March 13.

**Engine, New, Sectionalized**
for mule back transport, 170 HP. vertical 2 crank compound.—Address, H 351, Offices of ENGINEERING.

BARGAINS FROM BOLTON.
**Nearly New Pair of Self-**
CONTAINED HAULING ENGINES, by John Wood & Sons, Wigan.
Cylinder..... 12 in. diam.
Stroke..... 20 in. diam.
Very heavy cast-iron bedplate.
Double Helical Gearing. Link reversing motion, Winding drum, 4 ft. diam. by 3 ft. 6 in. wide. Flange 9 in. deep.
IN STOCK.
THOMAS MITCHELL & SONS, LTD.
BOLTON. 2405

**R. Y. Pickering & Co., Ltd.**
(Established 1864.)
BUILDERS of RAILWAY CARRIAGES & WAGONS
MAKERS of WHEELS and AXLES of all kinds.
Chief Offices and Works:
WISHAW, SCOTLAND.
London Office: Od 8353
10, IDDESLEIGH HOUSE, WESTMINSTER, S.W.1.

ON ADMIRALTY LIST.
**John Kirkaldy, Ltd.,**
London Office: 101, LEADENHALL ST., E.C.3.
Works: BURNT MILL, near HARLOW, ESSEX.
Branch Office and Depot: 14, SNOW HILL, BIRMINGHAM. 'Phone: Central 2775.
Makers of
Evaporating and Distilling Plants.
Refrigerating and Ice-making Machinery.
Feed Water Heaters. Evaporators.
Fresh Water Distillers.
Main Feed Pumps.
Combined Circulating and Air Pumps.
Auxiliary Surface Condensers, &c., &c. 2327

TRADE **"SUMMIT"** MARK.
**Slitting Saws**
AND SCREW SLOTTING CUTTERS.
JOSEPH THOMPSON (Sheffield) LTD.,
Townhead Street Engineering Works,
SHEFFIELD. 2677

Telegrams: "Epa," London.
Telephone: 7434 Central.
**E. P. Alexander & Son.**
CHARTERED PATENT AGENTS,
306, High Holborn, London, W.C.1. 585
PATENTS. DESIGNS. TRADE MARKS.

**Royles Limited,**
ENGINEERS, IRLAM, MANCHESTER.
FEED WATER HEATERS,
CALORIFIERS, EVAPORATORS, } Row's
CONDENSERS, AIR HEATERS, } Patents.
STEAM and GAS KETTLES
Merrill's Patent TWIN STRAINERS for Pump Suctions.
SYPHONIA STEAM TRAPS. REDUCING VALVES
High-class GUNMETAL STEAM FITTINGS.
WATER SOFTENING and FILTERING. 5723

**YARROW & CO. (1922), LTD., GLASGOW.**
LAND AND MARINE
YARROW BOILERS. 2277

**Matthew Paul & Co., Ltd.,**
LEVENFORD WORKS, Dumbarton. 2213
See Full Page Advt., page 58, Feb. 27.

**Forgings.**
**Walter Somers, Limited,**
HALESOWEN. 7116

**Taylor & Challen Presses**
For Production of SHEET METAL WORK, COINAGE, CARTRIDGES AND GUNPOWDER.
Foundry, Works and Showrooms: BIRMINGHAM.
See Advert., page 36, Feb. 27. 6195

**Head, Wrightson & Co.,**
LIMITED.
See Advertisement page 58. 2402

**Rosser and Russell, Ltd.,**
MECHANICAL ENGINEERS,
QUEEN'S WHARF, HAMMERSMITH, W.
Undertake SPECIAL MACHINE WORK of any description.
WELL EQUIPPED SHOP.
LATHE WORK up to 10 ft. diameter.
*'Phone:* Hammersmith 31, 967. 2211

**Railway Switches and Crossings.**
T. SUMMERSON & SONS, LIMITED,
DARLINGTON. 2702

**For Sale or to Feu, in Whole**
OR PLOTS.
68 ACRES OF GROUND AND BUILDINGS, suitable for Factories or Works, at Inchinnan, on the main road between Glasgow and Greenock.
One building, length 250 ft. by 150 ft., height 48 ft. to eaves, structure of brick and steel, lit from roof, contains approximately 37,500 sq. ft. floor space.
One building, in several bays, 330 ft. long at the longest part, 258 ft. broad, height, one part 24 ft. 6 in. to eaves, other part 16 ft. to eaves structure of brick and steel, lit from sides and roofs, granolithic floors, mechanically heated, contains approximately 83,000 sq. ft. floor space.
One building 320 ft. long by 160 ft. broad, height, 16 ft. 9 in. to eaves, with small annex 50 ft. by 30 ft., structure of brick and steel, granolithic floors, lit from sides and roof, mechanically heated, approximately 53,000 sq. ft. floor space.
Electric power is laid into each of these buildings from the Clyde Valley Power Station, also water supply.
For further particulars apply to:—
WEARING & MARTIN, Writers, 180, Hope Street, Glasgow. 2346

**New 300 & 500 B.HP. M.A.N.**
STATIONARY DIESEL ENGINES with accessories, as delivered from the makers under Peace Treaty; also Dynamos for same. All spare parts in stock.—HICK-DIESEL OIL ENGINES LTD., 70, Queen Victoria Street, E.C. 4. 2527

**British Bock Bearings,**
LIMITED.
Works and Offices: 120, Cornwall Street, Glasgow.
Branch Office: 4, Albert Square, Manchester.
Regd. Offices: 10, Princes St., Westminster, S.W.1.
**Adjustable Taper Roller Bearings.** 2696

## The Manchester Steam Users ASSOCIATION.

For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.
Chief Engineer: C. E. STROMEYER, M.I.C.E.
Founded 1854 by SIR WILLIAM FAIRBAIRN.
Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 2701

## Northampton Polytechnic INSTITUTE,

St. John Street, E.C.1.

A Special Course of SIX LECTURES on
THE METALLOGRAPHY AND HEAT TREATMENT OF IRON AND STEEL,
will be given on Thursday evenings, at Seven p.m., by
Mr. R. GENDERS, M.B.E., B. Met.,
commencing on March 19, 1925, as follows:—

March 19. Wrought Iron and Shear Steel.
,, 26. Properties and Heat Treatment of Carbon Steels.
April 2. Special Purpose Steels.
,, 16. Tool Steels.
,, 23. Defects in Steels.
,, 30. Cast and Malleable Cast Iro

These Lectures are open to the public without fee.

S. C. LAWS,
Principal. H 46

## Correspondence Courses for

Inst. Civil Engrs., Inst. Mech., London Univ. (Matric., Inter., B.Sc.), Inst.M. & Cy.E., and ALL ENGINEERING EXAMINATIONS personally conducted by Mr. TREVOR W. PHILLIPS, B.Sc. (Honours) Eng. London, Assoc.M.Inst.C.E., Chartered Civil Engineer. M.R.S.I., F.R.S.A., etc. Also Day Tuition in Office. Excellent results at all Exams., comprising hundreds of successful Students. Courses may commence at any time, and all Students receive individual tuition.—For full particulars apply to S/11, TRAFFORD CHAMBERS, 58, SOUTH JOHN STREET, LIVERPOOL. 2689

## Draughtsmen, before

Negotiating with Government Departments in connection with any post, please communicate with the GENERAL SECRETARY, Association of Engineering and Shipbuilding Draughtsmen, 96, St. George's Square, London, S.W.1. G 758

## Engineering Salesmanship

and SALES MANAGEMENT.—Write for brochure describing our special Course of Training for posts of unlimited scope in the lucrative field.—DIRECTOR, Institute of Engineering Salesmanship, 77, Milligate Building, Manchester. 2676


## TENDERS.

THE GREAT INDIAN PENINSULA RAILWAY COMPANY, 48, Copthall Avenue, London, E.C.2, invite

### Tenders for :—

1. CARRIAGE UNDERFRAMES, with 4-wheel Bogies. Fee £1.
2. CARRIAGE UNDERFRAMES, with 6-wheel Bogies. Fee £1.

Tenders are due by ELEVEN a.m. on 7th April, 1925. Tender forms obtainable at above address. Fees not returnable. H 536

GREAT NORTHERN RAILWAY (IRELAND).

TO STEELWORK CONTRACTORS.

The Directors are prepared to receive

### Tenders for the Supply and ERECTION of a SMALL STEEL AQUEDUCT,

between Newtownstewart and Victoria Bridge.

The Drawing and Specification may be inspected at the Engineer's Offices, Dublin and Belfast, and copies of same, together with Bill of Quantities and Form of Tender may be obtained from the undersigned on payment of Two Guineas, which will be refunded on receipt of a *bona fide* Tender.

Tenders made out on Forms supplied by the Company should be delivered, under sealed cover endorsed "Tender for Aqueduct," not later than Ten a.m. on Monday, March 23rd.

The Directors do not bind themselves to accept the lowest or any Tender.

J. B. STEPHENS,
Secretary.

Amiens Street Station,
Dublin.
10th March, 1925. H 512

BOROUGH OF BRIDLINGTON.

EXTENSIONS TO ELECTRICITY WORKS.

The Bridlington Borough Council invite

### Tenders for the Supply and ERECTION in their Electricity Works at

Britt Street, Bridlington, of the following:—
SPECIFICATION No. 3. MECHANICAL STOKERS, GRATES, FORCED DRAUGHT PLANT, COAL ELEVATORS, HOPPERS and SUPERHEATERS FOR EXISTING LANCASHIRE BOILERS.

A copy of the Specification can be seen at and obtained from the offices of Messrs. KENNEDY and DONKIN, 8, Broadway, Westminster, S.W.1, on and after Monday, the 16th March, upon payment of a deposit of £1 (cheque, postal order or money order). An additional copy of the Specification can be obtained upon payment of a deposit of 10s. 6d. These deposits will be returned after the receipt of a *bona fide* Tender, and on the return of the Specification.

Tenders on the prescribed Form, enclosed in sealed envelopes, and addressed on the outside:—"Extensions to Electricity Works, Tender to Specification No. 3," must be delivered at the office of the undersigned not later than Monday, the 30th March, 1925.

The Council do not bind themselves to accept the lowest or any Tender.

GEORGE MELVIN,
Town Clerk.

Town Hall, Bridlington.
March, 1925. H 514

THE DIRECTOR-GENERAL, INDIA STORE DEPARTMENT, Branch No. 16, Belvedere Road, Lambeth, S.E. 1, invites

### Tenders for :—

1. MATERIALS and FITTINGS for Railway Freight Vans.
2. WHEELS and AXLES.

Tenders due on the 7th April, 1925.
Tender Forms obtainable from above. H 553

TYNE IMPROVEMENT COMMISSION.

TIMBER JETTY AND STEEL SHEET PILING IN HOWDON YARD BAY.

THE TYNE IMPROVEMENT COMMISSIONERS are prepared to receive

### Tenders for the Construction

of a TIMBER JETTY and STEEL SHEET PILING at their Engineering Yard, Howdon-on-Tyne.

Copies of the Form of Tender, Conditions of Contract, Specification and Drawing may be obtained on application to the undersigned on payment of a deposit of £2 2s. which will be returned on receipt of a *bona fide* Tender.

Tenders in sealed envelopes, endorsed on the cover "Tender for Timber Jetty and Steel Sheet Piling," must be addressed to "The Chairman, Dredging and River Works Committee," and delivered at the undermentioned Offices not later than Noon, on Monday, the 6th proximo.

The Commissioners do not bind themselves to accept the lowest or any Tender.

By Order,
ALBERT BLACKLOCK,
Secretary.

Tyne Improvement Commission Offices,
Bewick Street,
Newcastle-upon-Tyne.
18th March, 1925. H 542

BOMBAY, BARODA AND CENTRAL INDIA RAILWAY COMPANY.

The Directors are prepared to receive up to noon on Friday, 3rd April,

### Tenders for the Supply of :—

1. SCREW COUPLINGS.
2. WHEELS AND AXLES FOR CARRIAGES AND WAGONS.
3. STEEL MATERIAL (PLATES, CHANNELS, ANGLES, ETC.).
4. AXLES FOR CARRIAGES AND WAGONS.
5. TYRES FOR CARRIAGES AND WAGONS.

Tenders must be made on Forms, copies of which, with Specification, can be obtained at these Offices on payment of 20/- each for Nos. 1, 2 and 3, and 10/- each for Nos. 4 and 5 (which will not be returned).

The Directors do not bind themselves to accept the lowest or any Tender.

S. G. S. YOUNG,
Secretary.

Offices: 91, Petty France,
Westminster,
S.W.1. H 537

## APPOINTMENTS OPEN.

### Applications are Invited

for a VACANCY as JUNIOR SCIENTIFIC ASSISTANT in the Experimental Department of H.M. Signal School, Portsmouth. Candidates, who should not be over 30 years of age, should possess an Honours Degree in Physics or its equivalent. (Preference will be given to ex-Service men.)

The salary scale is £175-15-235, plus Civil Service Bonus, which at present increases £175 to £278 19s.

The successful candidate will be required to contribute 5 per cent. of the basic salary under the Federated Universities Superannuation Scheme, the remainder being contributed by the Government.

Applications, giving full particulars of qualifications, War Service, etc., and enclosing testimonials, should be forwarded to the SECRETARY OF THE ADMIRALTY (C.E.), Admiralty, S.W.1, not later than April 7th. H 457

UNIVERSITY OF BIRMINGHAM.

FACULTY OF SCIENCE.

PROFESSOR OF CHEMISTRY AND DIRECTOR OF THE DEPARTMENT OF CHEMISTRY.

The Council of the University invites

### Applications for the Appointment of PROFESSOR of CHEMISTRY and DIRECTOR of the DEPARTMENT of CHEMISTRY.

Annual stipend £1100.

The Professor will be required to take up his duties on October 1st, 1925.

Twenty-four copies of application (accompanied by testimonials, references, or other credentials) should be received on or before May 1st.

Further particulars may be obtained from the undersigned.

C. G. BURTON,
Secretary. H 547

MINISTRY OF TRANSPORT.

ROADS DEPARTMENT.

### Applications are Invited

for a TEMPORARY APPOINTMENT as ASSISTANT ENGINEER for road work in the London Area on the range of salary £300/£400 per annum inclusive, according to experience and qualifications.

Candidates should be practical and experienced men with a knowledge of local administration and of modern road and bridge construction. Preference will be given to men who have served in His Majesty's forces.

Applications should be made immediately, in writing, to the ESTABLISHMENT OFFICER, MINISTRY OF TRANSPORT, 6, Whitehall Gardens, S.W.1, stating age, qualifications, experience and references. H 554

### Required, Assistant Works

MANAGER, near London, age between 30 and 40, with experience of high speed petrol and paraffin Engines. State salary and full particulars, —Address, H 520, Offices of ENGINEERING.

### Wanted, for Machine Tool

Works (West Riding of Yorks), GENERAL MANAGER. Capacity of works normally 80-100 hands. Old-established Firm with good reputation for its products. Splendid opportunity for man of real managerial ability capable of organising for good sales and quality output at competitive prices. —Applications (which will be treated in strictest confidence), giving full particulars, to WHITFIELD, Solicitor, Arundel Place, Scarborough. H 551

### Meter Tester and

REPAIRER REQUIRED for duty in WORKS AND BUILDINGS DEPARTMENT, AIR MINISTRY, IRAQ. Applicants must be ex-service, should preferably be unmarried and under 35 years of age, must have had not less than 5 years' workshop experience of the manufacture and repair of all classes of D.C. and A.C. electricity meters, together with outside experience of locating faults and effecting adjustments. Salary £450 per annum inclusive. Applications should be addressed to the SECRETARY, AIR MINISTRY (W.B.5), Kingsway, W.C.2. H 538

NORTHAMPTON POLYTECHNIC INSTITUTE, CLERKENWELL, LONDON, E.C.1.
HEAD OF THE ELECTRICAL ENGINEERING DEPARTMENT.
THE GOVERNING BODY invite

### Applications for the Vacant

POST of HEAD OF THE ELECTRICAL ENGINEERING DEPARTMENT.

The salary scale at present applicable to the post is £700–25–900 (less an abatement of 5 per cent.) The period during which the present scale (and abatement) is operative expires on March 31st, 1925, when some revision may take place following an award of the arbitrator appointed in connection with the joint standing committee on teachers' salaries.

The post is governed by the provisions of the Teachers (Superannuation) Acts.

Further particulars and forms of application may be had on application to the undersigned, to whom applications should be forwarded not later than April 18th.

S. C. LAWS, M.A., M.Sc.,
Principal. H 475

INDIAN SERVICE OF ENGINEERS.

THE SECRETARY OF STATE FOR INDIA IN COUNCIL will, in 1925, appoint

### Eight Assistant Executive ENGINEERS for this Service

if so many suitable candidates present themselves.

Every candidate must be a European British subject, and must be not less than 21 years and not more than 24 years of age on 1st August, 1925.

They must either (1) have obtained one of certain recognised University degrees or other distinctions in Engineering, or (2) have passed sections A and B of the Associate Membership Examination of the Institution of Civil Engineers or been exempted by the Institution from such examination, or (3) produce the required evidence that they are otherwise eligible under the Regulations. They must in addition have had at least one full year's practical experience of Civil Engineering under a qualified Civil Engineer at the time when they appear before the Selection Committee.

Applications from candidates must reach the India Office not later than 1st April. Printed forms, together with information regarding the conditions of appointment, may now be obtained from the SECRETARY, Public Works Department, India Office, Whitehall, London, S.W.1. H 234

COUNTY OF LONDON.

The London County Council invites

### Applications for the Position

of POWER STATION ENGINEER at its Greenwich Power Station in its Tramways Department.

The salary will be £600 a year, rising by annual increments of £50 to a maximum of £700 a year. The salaries mentioned are based on pre-war conditions and are subject at present to temporary additions on the Civil Service scale, fluctuating according to the cost of living. The total commencing remuneration at the present time on the existing basis is £801 10s. 7d. a year.

Candidates must be fully trained and qualified engineers and have held a responsible position in a large generating station.

Candidates not already in the Council's service must be not less than 35 and not more than 50 years of age on the latest day for receiving applications. Preference will be given to candidates who served or attempted to serve with H.M. Forces during the Great War.

Apply for forms (containing full details) to the Clerk of the Council, The County Hall, Westminster Bridge, S.E.1 (stamped addressed foolscap envelope necessary). Forms must be returned so as to be received not later than Twelve o'clock Noon on Tuesday, 14th April, 1925. Canvassing disqualifies.

MONTAGU H. COX, H 509
Clerk of the London County Council.

BURMA RAILWAYS.

THREE ASSISTANT ENGINEERS.

The Directors are prepared to receive

### Applications (by letter only)

from properly qualified Candidates for APPOINTMENT as ASSISTANT ENGINEERS in Burma.

Applicants must be between 22 and 28 years of age (bachelors preferred), and be active and of good physique. They must have had at least three years' training in a recognised Engineering College and hold an Engineering Degree or have passed the A.M.Inst.C.E., Examination, and have had practical experience with a Railway Company or on Public Works of not less than one year.

SALARY: Rs. 550 to commence, rising by annual increments of Rs. 50 to Rs. 1100 per calendar month.

TERMS: A three years' agreement in the first instance, with first-class free passage to Burma and home again on satisfactory termination of services.

The selected candidate will be required to pass a strict medical examination by the Company's Consulting Physician before final appointment.

Applications, giving all the particulars called for above, and showing candidate's career in chronological order (with dates), should be addressed to the undersigned not later than the 2nd April, 1925.

SECRETARY, H 510
199, Gresham House,
Old Broad Street,
London, E.C.2.

### Engineer-Salesman Wanted

by prominent London Firm. Must be keen, energetic and a real worker. Quick advancement for suitable man. State age, education, training, selling experience and salary.—Address, H 542, Offices of ENGINEERING.

### Reinforced Concrete Engineer.

—A Leading Firm of Reinforced Concrete Designers REQUIRES a CAPABLE and ENERGETIC ENGINEER to take charge of a portion of the Drawing Office staff. Specialist design, experience and executive ability essential.—Applications, giving full tabulated summary of qualification and experience and stating age and salary required, will be treated in strict confidence, and should be addressed in the first instance, to H 546, Offices of ENGINEERING.

### Chief Engineer Salesman,

REQUIRED to take charge of Sales Department of large firm supplying CENTRIFUGAL LIQUID PURIFIERS. Unique opportunity for suitable man, who must have initiative, organising ability, extensive sales experience, and preferably some knowledge of centrifugals. State age and salary required, and give full particulars of qualifications and experience.—Address, H 445, Offices of ENGINEERING.

### Assistant Engineers Required

for Chief Engineer's Department of important Argentine Railway. Age 25-32. Applicants should have had previous Railway experience, either on construction or maintenance, and should have qualified or be qualifying for A.M.Inst.C.E. Three years' engagement at salary of £450, £500 and £550, plus £50 when working knowledge of Spanish has been acquired. Free passage.—Please give details of education, training, experience, age, etc., with copies (only) of testimonials to BOX Q.R.D., c/o DAVIES & Co., 95, Bishopsgate, E.C. H 548

### The South Metropolitan Gas COMPANY has a VACANCY for an ENGINEER

with wide experience in the design, construction, erection and repair of Gasholders, Retort and other manufacturing plant and structures of the kind used in Gasworks and Coke Oven Recovery.

Applications, giving age, full particulars of qualifications, experience, military service and salary required, should be made in writing to the undersigned before 31st inst.

By Order,
FRANK DAY,
Secretary.

709, Old Kent Road,
London, S.E. 15.
14th March, 1925. H 550

CITY OF BIRMINGHAM ELECTRIC SUPPLY DEPARTMENT.

ASSISTANT TO CONSTRUCTIONAL ENGINEER.

DRAUGHTSMAN.

### Applications are Invited for

the following APPOINTMENTS:—
(1) ASSISTANT TO CONSTRUCTIONAL ENGINEER.

To assist in the preparation of Specifications and Plans for new buildings, lay-out of boilers, turbo-alternators, etc.

Candidates must be corporate members of the I.E.E. or of the I.Mech.E.

Salary—Class J, Grade 8, National Joint Board's Schedule. Present net amount £430 per annum.

(2) DRAUGHTSMAN IN CONSTRUCTIONAL ENGINEER'S DEPARTMENT.

Salary—Class J, Grade 9, National Joint Board's Schedule. Present net amount £342 per annum.

Candidates for both appointments must have served an apprenticeship to Mechanical Engineering and had experience of the latest practice as applied to the design of large Electric Stations.

The successful candidates will be required to undergo an approved medical examination and contribute to the Corporation's Superannuation Scheme.

Forms of application for these appointments may be obtained from the undersigned and will require to be returned with copies of not more than three recent testimonials by the 6th April.

E. J. JENNINGS,
Secretary.

14, Dale End,
Birmingham,
March 13th, 1925. H 523

BOMBAY, BARODA AND CENTRAL INDIA RAILWAY.

ASSISTANT SIGNAL ENGINEER.

The Directors are prepared to receive

### Applications (by letter only)

from properly qualified candidates for APPOINTMENT as ASSISTANT SIGNAL ENGINEER on the above Railway.

Candidates should be between 25 and 30 years of age, and must have had a Public School or good Secondary School education, and a technical education in Mechanical and Electrical Engineering at a recognised Engineering College. They should have served a full course in a Railway Signalling Workshop and should have a thorough knowledge of modern Railway signalling practice, including the preparation of signalling schemes, and the installation and maintenance of same. Preference will be given to a candidate with experience in the manufacture and maintenance of single and double line block instruments.

COMMENCING SALARY: Rs. 450 per calendar month, or such higher salary as may be justified by age and qualifications.

TERMS: A three years' agreement in the first instance, first-class free passage to India and home again subject to satisfactory termination of services.

The selected candidate will be required to pass a strict medical examination by the Company's Consulting Physician before appointment.

Applications (by letter only), giving age, whether married or single, and full details of general and technical education, together with a statement (with dates) of candidate's career in chronological order, and showing in what departments training and subsequent experience has been obtained, and class of work employed upon, should be addressed to the undersigned not later than the 3rd April, 1925.

S. G. S. YOUNG,
Secretary.

Offices: The White Mansion,
91, Petty France,
Westminster, S.W.1.
13th March, 1925. H 524

1925.

Wanted
ust be keen,
dvancement
n, training,
ress, H 585.

Engi-
ed Concrete
NERGETIC
tion of the
, experience
tious, giving
and experi-
ired, will be
e addressed,
Offices of

lesman,
ales Depart-
TRIFUGAL
rtunity for
, organising
d preferably
ate age and
of qualifica-
5, Offices of

equired
at of impor-
Applicants
experience,
and should
M.Inst.C.E.
50, £500 and
e of Spanish
Please give
ce, age, etc.,
OX Q.R.D.
H 548

an Gas
ENGINEER
onstruction,
t and other
f the kind
ery.
ars of quali-
and salary
the under-

DAY,
Secretary.

H 550

C SUPPLY

NGINEER.

ted for
:—
NAL ENGI-
ications and
ilers, turbo-
bers of the
oint Board's
r annum.
UCTIONAL
T.
oint Board's
r annum.
must have
Engineering
e as applied
required in
nation and
erannuation
tments may
will require
than three
GS,
Secretary.

H 522

AL INDIA

ER.
ceive
r only)
idates for
NAL ENGI-
30 years of
hool or good
technical
Engineering
They should
Signalling
knowledge
including
s, and the
Preference
ence in the
and double
dar month,
by age and
the first
and house
of service.
to pass a
Company's
t.
ge, whether
general and
statement
hrenological
ts training
tained, and
addressed
April, 1925.
NG,
Secretary.

H 556

## SMALL HYDRO-ELECTRIC UNITS.

(*Continued from page* 281.)

*Governing.*—The method whereby the amount of water supplied to a Francis turbine is changed according to the load has already been outlined, and the system of pivot gates moving in unison made clear. The pivot gate system has quite superseded the register and cylinder gates of the old stock pattern turbine, which although cheap to construct were unsuitable for close governing, besides having other defects. In Figs. 4 and 10 of our previous article, and Fig. 11, on this page, the governors of the units are seen, while a near view of the governor of the unit shown in Fig. 11 is given in Fig. 12. This machine is a 500 h.p. spiral Gunther Francis turbine for a 62 ft. fall. It may be taken as typical of modern practice. It is impossible to go fully into the question of governing hydraulic turbines in this article, but the system may be briefly described. A pump driven off the turbine shaft maintains oil under pressure in a receiver. With large installations this oil pressure is maintained by compressed air, but this does not apply to small installations. A ball governor, driven by the turbine controls the flow of this oil to one end or the other of a cylinder. In this cylinder is a piston, the rod of which is connected by an arrangement of links seen in Fig. 11 with the control ring of the turbine. It will be clear that a greater or smaller amount of oil admitted to one end or other of the operating cylinder of the governor, will serve to close or open the gates. This closing and opening motion is going on imperceptibly all the time under control of the sensitive ball governor and a compensating gear, the latter being an important adjunct. In the example illustrated in Fig. 12 the movement of the operating piston gives an angular movement to the shaft seen on the left of the casing, which, by links connected to the arm shown on it, transmits the motion to the control ring. The hand wheel, worm and worm wheel are for the purpose of closing the gates by hand. Practically all modern governor systems work on this principle, and as will be seen later, these oil pressure governors are applied to moving the deflector of a Pelton wheel, and in some cases to the combined movement of the needle and deflector.

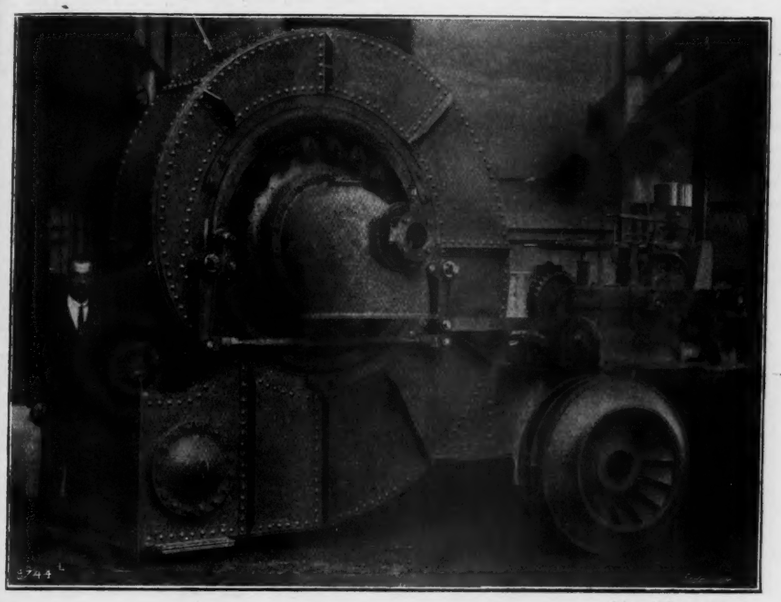


FIG. 11. 500-H.P. SPECIAL GUNTHER FRANCIS TURBINE.

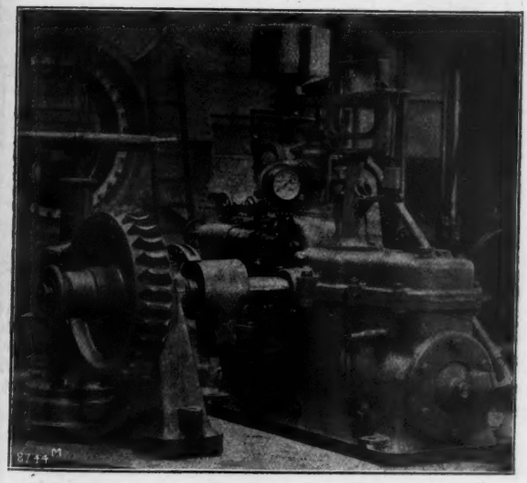
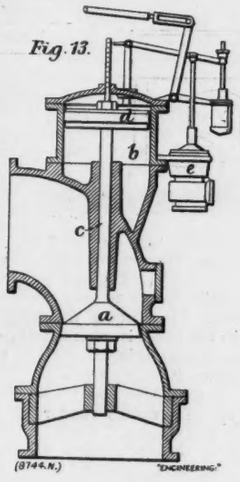


FIG. 12. GOVERNOR FOR GUNTHER FRANCIS TURBINE.

*Fig. 13.*




*Pressure Regulators.*—It is important to ensure that, upon the closing of the gates of a turbine suddenly, due to an abnormal condition of load, shock will not be set up in the pipe line. The normal closing of the gates would be very slow, but dangerous pressure might be set up under certain circumstances. To cope with this a pressure regulator is often installed, one of these being shown on the right-hand side of Fig. 10, immediately in front of the turbine. A sectional diagram of the apparatus is given in Fig. 13. The flange on the left-hand side is connected to the pipe line or with the turbine casing. Valve *a* is normally held on its seat by pressure admitted to cylinder *b* under piston *d*, which is mounted on the valve spindle *c*. The valve *e* which controls the flow of water under pressure to the cylinder *b*, is either operated by the governor or it immediately responds to any increase of pressure in the pipe line. That is, it is either governor-operated or pressure-operated, usually the former. When the governor closes the gates more than a certain amount at one movement, the pressure in *b* is released through *e*, allowing a certain amount of water to escape from the pipe line past *a*, so that the flow therein for a short period is gradually diminished. After a short period of time the valve *a* slowly closes, so that although the turbine gates may close as rapidly as desired, the flow of water in the pipe has time to settle down to the new conditions without setting up shock.

*Turbines for very Low Falls.*—None of the turbines previously described is suitable for very low falls. About 25 ft. is the lowest economical limits for units of the class shown in Fig. 1, of our previous article, unless low speeds are admissible. The development of low falls is always a perplexing problem for the hydraulic engineer, but it is very often desirable to utilise them, especially in cases where old waterwheels, which invariably operate under low falls, have ceased to provide the power required. Such conditions either mean installing fuel plant or modernising the water power.

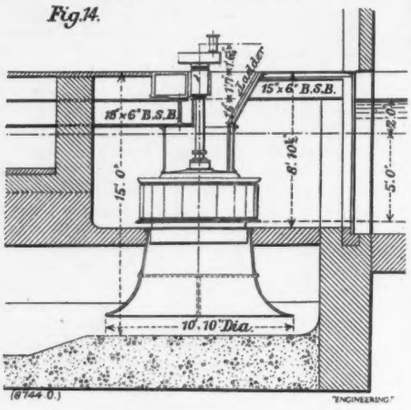
*Vertical Turbines. The Hydraucone.*—The small vertical shaft turbine is in a sense a reversion to the stock pattern type already mentioned, but it must not be lost sight of in its modern form as a feasible means of developing very low heads. The speed is, of necessity, low, and unless gearing is installed, the generators must be of the vertical type. There is no great objection to vertical generators; the very largest hydro-electric units are built on this principle, but with low falls the generators become heavy for the output obtained. The principle development in connection with the low-fall vertical turbine of recent years is the hydraucone. This arrangement has nothing to do with the runner, but is essentially a device for improving the efficiency of low-fall turbines at the draft tube end. The idea is illustrated in Fig. 14. The arrangement for the hydraucone takes the form of a flat plate on which the water from the draft tube will impinge. This is placed in the concrete setting of the discharge. The arrangement is quite feasible with a horizontal turbine, a diagram of which is given in Fig. 15.

*The Banki Turbine.*—This is a new development in low-fall turbine construction. The special advantages claimed for it when working under very low heads are high efficiency at all gate openings, high speed, simple foundations, no building required to house the turbine and a capacity to work when completely drowned by the tail water.

In arrangement the Banki turbine bears a strong resemblance to the old Poncelet water wheel, but unlike the latter the vanes are quite open at the back and water is permitted to pass through the buckets, across the open centre portion of the wheel, and thence to make a second passage through the buckets to the opposite side in the reverse direction. At each pass the water is deflected and gives up its energy, eddies and shocks being nullified and the water issuing quietly into the tail race. Although essentially a machine for operating on the lowest heads, the Banki turbine is not confined to such conditions. Being extremely simple and requiring the minimum amount of setting it is very suitable for plants where the capital cost must be kept low. The arrangement of a turbine of this class operating on a 23 ft. head is shown in Fig. 16, the output being 130 b.h.p. at a speed of 115 r.p.m. It will be noted that a chain drive is installed, by means of which the necessary speed increase to 500 r.p.m. for the generator is effected in the minimum

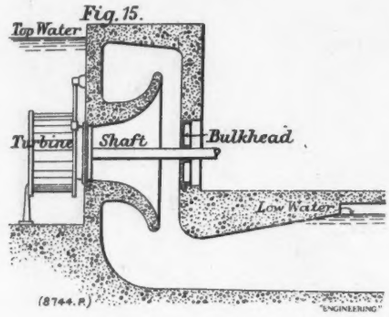
of space. This unit is fitted with a governor, and the Banki turbine is quite capable of close governing. The means by which this is carried out is a deflector which diverts the course of the water during the interval that the gate is being slowly closed by the governor mechanism. The system, therefore, approaches in action that of the spear and deflector system used with Pelton wheels, and effects close governing with economy of water. This turbine, although quite a new introduction would appear to have a wide application in the development of low falls. It is simple and reliable in operation, not costly to build nor instal, while the governing mechanism is simple. Moreover, good efficiencies are obtainable with it at part gate, figures given by the builders relating to a wheel developing 57 h.p. showing an efficiency at full load of 84 per cent. and not less than 60 per cent. at ½ load.

Fig. 14.




to the single-wheel Francis with quarter bend discharge. The runner *a*, however, is quite different, being much like a short-bladed screw propeller. The suction tube *b* is also of special form and will be referred to again. In the Francis turbine, the runner blades are comparatively long in an axial direction. Long channels are formed and at high velocities there is considerable friction, setting up considerable loss in addition to impact losses at entry, and eddy flow losses at discharge. These are known to exist in high-speed Francis turbines. It is these losses which the Kaplan runner aims at overcoming. The runner *a* consists of two or at the most, four blades, and these are adjustable as to angle according to the speed, the adjusting gearing being shown at *e*. It actuates a cam gear in the shaft, which is hollow. The direction of flow leaving the runner is axial and is free from any rotational component and losses inherent therein, while since the inlet angle of the wheel practically always corresponds to the angle of the guide vanes *c* the impact losses are reduced to a

Fig. 15.




pivoted guide vane system of the Francis turbine, these being shown at *c*, the governing system provides for the moving of the runner blades in synchronism with them, and the whole arrangement follows, more or less, orthodox hydraulic turbine governing, making use of the servo-motor principle. Arrangements are made for an abnormal opening of the runner blades if required to permit of heavy overload.

There is no doubt that the propeller type of turbine, of which the Kaplan is one, presents several advantages over the Francis for certain conditions. The principal one is its high speed with high efficiency. In addition it has a high capacity for over-

Fig. 17.

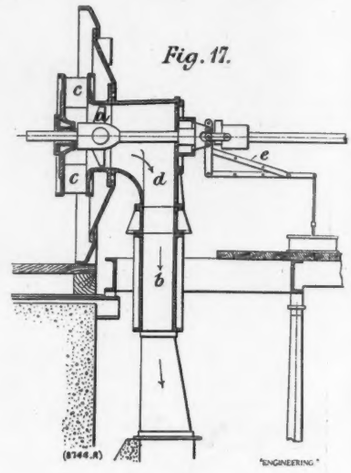
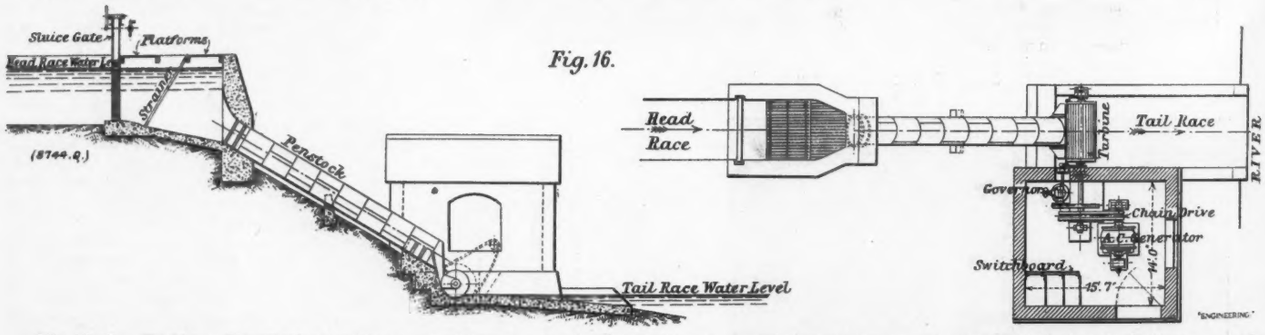



Fig. 16.




*The Kaplan Turbine.*—The Kaplan turbine is a comparatively new development in turbine construction involving propeller type runners. The object of these runners is to give increased speed under given conditions. It is well known that with an increased specific speed the efficiency of the orthodox reaction turbine falls off; especially is this so at loads other than full load, and despite the fact that experimental units have been built with runners having very high specific speeds the usual limit is reached at about 400. In the original Kaplan turbine, which was a little copper model with a 4 in. diameter runner operating in a glass "setting" under a head of 19 in., the runner had a specific speed of 500 to 900 and gave remarkable results.

Practical machines involving two main patents appeared in 1916, while another built in 1920, having a 12-in. runner operating under a head of 3 ft. 3½ in., had a specific speed of 808 and showed an efficiency of 83·2 per cent., which only fell to 75·3 per cent. at a specific speed of 1,156. The patents referred to have reference to runners with blades whose length in the direction of flow is shorter than the corresponding pitch of the blades, that is to say the blades viewed in the direction of the shaft do not overlap as in the Francis, and also to a means of altering the blade angle by turning them on their axis, the action being much the same as the reversible marine propeller.

The arrangement of the turbine is shown in Fig. 17, from which it will be seen that in this particular case it bears a good deal of resemblance

minimum even down to half gate. Thus, by adjusting the runner blades according to the load both inlet and outlet angles keep their correct relative values to each other over a large range of load. The effect of the design is that the flow at the discharge is in an axial direction, the rotational component being eliminated and the action of the suction tube improved.

It should be noted also that the water in this type of propeller runner follows the back surface of the blades. There is no tendency for the water to slip through the turbine without doing useful work, as might at first be supposed from the fact that the blades do not overlap, while there are no blade rings.

The draft tube plays an important part in the functioning of this turbine, but the ordinary form is not suited to the high discharge velocities of the Kaplan turbine, hence the adoption of the form shown at *d*. This causes the water to spread out in the flattened part of the suction pipe where the necessary conversion of energy takes place. This horizontal arrangement, however, is not essential, the Kaplan turbine can be quite well arranged as a vertical shaft turbine and units of this class have been built, the arrangement of the setting, pivoted guides, &c., and a modified hydraucone draft tube following pretty closely that of the vertical shaft Francis turbine. The horizontal arrangement, however, is generally to be preferred for small units.

While retaining the essential features of the load, and the turbine is adaptable to a wide head variation by merely altering the permanent set of the blade angle. The runner being comparatively simple eliminates a good deal of intricate foundry work and being light is easily transported. While it might be objected that movable blades would be best avoided, the mechanism is really quite simple and can be well protected from corrosion by packing with grease, forcing it in under pressure.

*(To be continued.)*

---

DYE TESTS FOR FIREBRICKS.—Colouring tests, now for some time used for the distinction of the constituents of complex minerals, are proposed by Dr. E. Steinhoff and F. Hartmann, of the Dortmund Union, for the examination of firebricks. When dyes are applied to minerals, the dye may either lodge in pores, or sink into fissures, or colour the whole surface, if it adheres at all. In many cases there will be no adhesion except after a previous etching which leaves a colloidal film on the surface. Steinhoff and Hartmann etch for periods of up to 24 hours at 50 deg. C. to 60 deg. C. with hydrochloric acid and aluminium chloride, and recommend as dyes methylene blue and anthraparparin. The specimen may be a brick, a powder or a microscopic slide. With methylene blue unbaked clay turns deep blue; above 900 deg. the colour becomes pale; clay baked at 1,200 deg. is no longer coloured. Quartz does not take the dye even after etching, except when heated above 1,200 deg. C. The yellow-brown grains of iron oxide remain unchanged. Thus dye tests we read in *Stahl und Eisen* for March 5 (page 338), give some information on the temperatures to which bricks have been heated and regarding their structure, and indicate that certain quartzites would not be suitable materials for firebricks.

## THE INSTITUTE OF METALS.

(*Concluded from page* 330.)

### LOCALISED CORROSION.

THE last paper taken at the morning meeting on Wednesday, the 11th inst., dealt with "Surface Abrasion as a Potential Cause of Localised Corrosion." Mr. U. R. Evans, the author, read it in abstract.

The paper referred to former work which indicated that most cases of serious corrosion were of an electro-chemical character. Electro-chemical action usually gave rise to soluble primary corrosion products, whilst direct chemical oxidation would generally produce an insoluble body *in situ* on the metallic surface, which would tend to obstruct further attack. Dr. Bengough had shown that local abrasion, by causing removal of the obstructive film, might allow local attack, whilst Mr. von Wurstemberger had suggested that very severe corrosion might be occasioned by electric currents flowing between the bare abrased portion and the still encrusted area. An investigation was made regarding the existence of such currents. Sometimes they flowed in such a direction as to localise corrosion on the small abrased portion, sometimes in the contrary direction. But they were generally transitory, dying away soon after abrasion ceased. Moreover, the abrasions required to produce these currents had, in most cases, to be sufficient to damage the metal by mechanical erosion also. In the case of the corrosion of zinc by hydrochloric acid, the wiping away of the black scum of residual impurity (lead, &c.) actually diminished the rate of attack; the impurity, if allowed to accumulate, acted as the cathodic members of the corrosion-couples and facilitated the liberation of hydrogen. Vernon's statement that commercial (impure) zinc was attacked more slowly than some grades of much purer zinc was confirmed; probably "homophase" impurity (in solid solution) behaved in the opposite mode to "heterophase" impurities (present as a separate phase).

Dr. Bengough, in discussion, said abrasions varied in importance from the practical point of view, as was evidenced in the case of condenser tubes and other piping, which were attacked to a great extent. The author had shown the influence on the abrasive attack of chloride solutions, sometimes anodic and sometimes cathodic; this was largely dependent upon the nature of the abrasion. When metals were attacked with water only, there was no mechanical erosion of the metals on which there was no chemical attack. In some there was a definite anodic effect in those conditions. With reference to the conclusion to the effect that soft erosion did not lead to serious attack because the erosion agent was too soft to attack the metal, one had to distinguish between true erosion of the metal and erosion of the scale. Mechanical erosion of the scale led to undercutting of the metal.

Dr. Vernon expressed his general agreement with the paper, and Mr. Evans, in the course of his brief reply, agreed that a water jet was in a sense a soft form of abrasion, but in this case, powerful capillary forces came into play which pulled away the scale from the metal. Sand was capable of causing some mechanical erosion. Generally, he was more in agreement with Dr. Bengough's arguments than Dr. Bengough was with his (the speaker's) on the same subject.

At the meeting on Wednesday afternoon, the chair was again taken by the President, Professor T. Turner.

### COMMERCIAL COPPER ROD.

The first paper taken was contributed by Mr. T. G. Bamford, M.Sc., and described "Comparative Tests on Some Varieties of Commerical Copper Rod." We reprinted this paper on page 331 of our last issue.

The discussion was opened by Mr. F. Tomlinson, who said that it had been known for years that tough pitch copper was damaged by heating it in a reducing flame, and that deoxidized copper was not so susceptible. In practice, however, "gassing" temperatures were never reached in the case of locomotive fire-box plates and stays, so that 95 per cent. of the locomotive builders used arsenical "tough pitch" copper for firebox plates and stays. This would be impossible if there were any danger of gassing. As a matter of fact, the liability of such plates to gassing, if heated to 500 deg. C. or 600 deg. C., was of no more interest to the locomotive builder than that the copper would melt if heated to 1,100 deg. C. With the temperatures actually attained, gassing would not occur even in an atmosphere of pure hydrogen, and failure from this cause were unheard of in locomotive practice. It was the workers on copper, not the users of the finished article, who had to guard against gassing. To-day, however, failures from this cause were rare as the necessity of maintaining an oxidizing flame when heating copper highly was generally realised. Some of the smaller coppersmiths and plumbers, however, did not know this, and by heating copper red-hot in a reducing flame, ruined the metal. The damage done did not, however require for its detection elaborate series of experiments, such as those described by the author. Gassed rods would break in the process of screwing, and in all cases such metal would be detected before use. He had never seen a failure of a plate or stay-bolt by gassing, but 20 years ago he had met with a plate thus damaged to the depth of $\frac{1}{32}$ in. This, however, was on the water side of the plate, and the damage could not, therefore, have arisen in use. The improvement in some of the properties of nickel copper by heating it in hydrogen was new to him, and it would be interesting to learn how this phenomenal result was brought about. The author had summed up against "tough pitch" copper, but in normal use, it did not seem that the nickel copper would be greatly superior. "Tough pitch" copper had the advantage that it could be made in large batches in very consistent quality. There were cases, however, where nickel copper was called for. For example, in some parts of South America, where the water was phenomenally bad, copper-nickel with 5 per cent. of nickel had been used, and even 10 per cent. of nickel had been adopted for stay bolts, and plates with the same nickel content were now being inquired for.

Mr. A. J. G. Smout, who followed, said that works experience confirmed the author's conclusions as to the advantages of the 1½ per cent. nickel-copper alloy which was now being used for stays in the fire zone of locomotive fire-boxes and also, to some extent, for plates. He thought that the last speaker had not been quite fair in confining his attention to the resistance to gassing, though he agreed that this was rarely met with in practice. The nickel-copper alloy was, however, not merely more resistant to gassing, but had better mechanical properties than the other varieties. The advantage in this regard would have been emphasised had the author tested his specimens hot instead of cold. The elastic limit of the nickel-copper alloy remained unchanged up to a temperature of 300 deg. C., whilst with Delta metal containing 2 per cent. of nickel there was a fall of 60 per cent. at this temperature. He believed that the 1½ per cent. nickel copper was eminently suitable for locomotive work.

Dr. H. Moore considered the paper really useful and practical. He believed that the advantages of deoxidised copper were insufficiently appreciated by engineers, though it might be true, as Mr. Tomlinson suggested, that it was not required for fire-box plates and stays. There were, however, other uses of copper, and he had known cases of failure, due to gassing, of tough-pitch copper used for oil heaters. In this case the trouble was got over by adding 2 per cent. of zinc. The coppersmith concerned had, however, no idea that the trouble could have been avoided by the use of deoxidised copper.

Mr. W. E. Ballard spoke next, and agreed that Mr. Tomlinson had been too hard on the author. Railway engineers might not have much trouble with gassing, but he had known the ends of copper tubes burnt out, he thought from this cause. He did not think that engineers were altogether to blame for not using deoxidised copper, since this material had not been "pushed" much by makers. It had the disadvantage of being more expensive and more difficult to make, and in railway shops trouble was experienced in screwing it, but this, he thought, could be got over by changing the tool. He was surprised that the author had not found more difference between nickel-copper and "tough pitch" copper in the matter of scaling. Sir Henry Fowler had quoted a case in which gassing occurred with copper credited with only 0·015 per cent. of oxygen. He (the speaker) thought that this might be due to the use of a bad casting in the extrusion process, whereby an oxidised layer might be formed as an inclusion in the finished rod. Copper being very pervious to hydrogen, this layer would be reached and reduced, thus splitting the metal.

Mr. Gibbins thought that the value of the paper depended wholly on the samples examined, which he held to be insufficiently pure for such a research. He could not understand how so much oxygen remained in the nickel-copper in view of the relatively large percentage of phosphorus also present. The tough-pitch non-arsenical copper contained, he thought, too much iron to be typical, the amount being sufficient to affect its mechanical properties, which would, he considered, have been improved had pure copper been used. If the nickel copper could be regarded as typical, he thought its properties would be well worth further study.

In reply, Mr. Bamford said that, although it was general knowledge that copper containing oxygen could be gassed, it had not been settled how much oxygen sufficed for this to occur. Sir Henry Fowler had said that gassing had occurred with as little as 0·015 per cent of oxygen. In view of this, the author had taken special pains to determine accurately the oxygen-content of his materials. He had thought it best, moreover, to work with commercial copper rather than with specially purified material. The important point brought out was that in some cases the tensile strength and the hardness were improved by the heat treatment given.

### THE BRITTLE RANGES OF BRASS.

The next paper taken was entitled "The Influence of Lead and Tin on the Brittle Ranges of Brass." Its author was Dr. D. Bunting. This paper is reproduced in abstract on page 368.

The discussion was opened by Dr. J. A. Jones who said that experiments on a great variety of material had been made at Woolwich in order to determine the effect of temperature. Included in their materials were brasses, but the range covered was not as wide, as that of the author. With a 70–30 brass they found that ½ per cent. of lead caused a rapid fall in the impact strength from 200 deg. to 350 deg. C., and that there was no recovery at higher temperatures, and very similar results were obtained with 1·7 per cent. lead. With 0·02 per cent. of lead there was also a fall, but there was some indication of recovery at the higher temperatures. With 0·01 per cent. lead the impact figure became very low between 500 deg. and 650 deg. C. and then rose again, attaining a maximum at 800 deg. C., which was followed by a rapid fall. With less than 0·01 per cent. of lead a minimum impact strength of 6 ft.-lb. was reached between 500 deg. and 650 deg. There was then a recovery, a figure of 60 ft.-lb. being attained at 850 deg. C. They concluded therefore that the amount of lead required to change the impact-temperature curve lay between 0·01 and 0·02 per cent. They had found for 70–30 brass a somewhat narrower brittle range than the author, but the Woolwich experiments were made with rolled material.

Professor Turner said that the importance of the research lay in the fact that where there was "recovery" hot-rolling became possible and, hence, a 70–30 brass, if sufficiently pure, could be rolled hot. This was not known 20 or 30 years ago, when it was usual to teach students that this procedure was only possible with the 60–40 brasses.

In reply, Dr. Bunting said that he had worked solely with castings, and he could quite believe that there might be difference with worked metal, particularly in the case of the $\beta$ brasses.

### BOUNDARY OF THE ALPHA PHASE.

A paper by Messrs. R. Genders and G. L. Bailey on "The Alpha Phase Boundary of the Copper-Zinc System" was next taken. This described some very careful work carried out at Woolwich with a

view to determining with precision the boundary of the alpha phase in the copper-zinc equilibrium diagram. A new feature was the use made of the instability produced by straining the metal, to reduce the time required for annealing. The strained condition was produced by quenching the alloys in brine, and afterwards annealing them at 450 deg. C. With this procedure, with an alloy containing 61·1 per cent. of copper, the transformation from a structure composed almost totally of $\beta$ to one of pure $\alpha$ was completed in one hour's annealing. The range covered in the experiments was from 75 per cent. to 55 per cent. of copper.

The discussion was opened by Dr. Taylor who said that she had been engaged on similar work at the National Physical Laboratory, but not hitting on the idea which was described in the paper her process required weeks instead of the hours occupied by the authors. Her results closely coincided with theirs.

Dr. Rosenhain, who followed, observed that the paper, dealing mainly with a single line on the equilibrium diagram, represented more work than commonly formed the basis on which writers elaborated complete diagrams of complicated systems. One line determined as the authors had done it was worth far more than the usual large scale rough sketches.

Mr. Stockdale, who spoke next, said that he had also studied the boundary of the $\alpha$ phase. He thought that the authors' method of heat treatment was not quite so efficient as had been claimed, as with chill cast alloys he found an annealing of three days was required to get a uniform solid solution. His results, however, generally corroborated those of the authors.

In reply Mr. G. L. Bailey expressed his gratification at the confirmation by Dr. Taylor and Mr. Stockdale of the results given in the paper, and expressed his surprise that the matter had not previously been worked out with accuracy. As to the time required, they were unable to detect any $\beta$ in $\alpha$ after annealing for the times stated.

### Red Stains on Brass.

Mr. E. A. Bolton then read a paper on "The Removal of Red Stains from Brass." In this paper various methods of pickling were discussed, particular attention being paid to dichromate-sulphuric acid solutions, which were found to provide the most effective means of removing the red stains. The strength and the temperature required, however, to be suitably adjusted, and the metal should be dipped for the least possible time, especially when fresh solutions were being used. High temperatures were to be avoided, and after removal the metal should be very thoroughly washed. He stated that though red stain could be removed by the means described in detail in his paper, the ideal was to avoid its production in the first instance, and as matters stood to-day this ideal was largely realised.

Dr. Turner asked what would be the effect of an addition of HCl to the sulphuric-nitric solutions used by the author.

Dr. Brownson suggested that in the author's diagrams it would have been better to plot the percentage of chromic acid, rather than the amount of chromate present. Red stain troubles were steadily disappearing, but some users preferred red-stained brass as it soldered more easily.

Mr. Smout said that the authors' work had already influenced practice, as confidential reports had been made to the members of the research association before the publication of this paper. Cleaner and better metal was being provided, and red stains were much rarer than 10 years ago.

Dr. Bowers said that the dichromate was not the effective agent in the authors' solutions, but the chromic acid. The latter had been used in some American works for years.

Mr. Brook, referring to the use of dichromate solutions said these were expensive, and any auxiliary processes ought to be cheap. He suggested therefore the use of an acid cupric chloride solution.

Professor Turner said that he had found red stain produced under an asbestos pad used to hold a tube which was being heated in a Bunsen burner. He believed this was due to some impurity in the asbestos.

In reply Mr. Bolton said that below the stains there was a gradual change from copper to brass, and on annealing there might be diffusion of Zn into the stain. Although the prevention of red stain was better than its cure, he had noted that the surface left after his treatment was very resistant to tarnish, which might be useful for certain purposes. He did not agree with the suggestion that it would have been preferable if he had used the chromic acid content in plotting his diagrams, rather than the proportion of dichromate present, as it was the dichromate salt which was actually used in the works.

### Density of Brasses.

The first paper taken at the meeting on Thursday, the 12th inst., dealt with "The Density and Constitution of the Industrial Brasses," by Mr. G. L. Bailey and Mr. R. Genders. It was read in abstract by the former. We hope to reproduce it later.

The discussion was opened by Dr. Rosenhain, who referred to the authors' application of a small amount of cold-work to their specimens, in order to ensure the absence of cavities, the cold-rolling being insufficient sensibly to affect the density, and asked how they knew that such was exactly the case. The authors should have prepared perfectly sound castings, not requiring any further treatment; that was a more satisfactory basis to work upon than the taking as a basis material which had been cold-rolled. Their remark that rapid cooling through the freezing range was without effect on the net density value was not surprising. The authors should ascertain the effect of grain-size; it was small, but its effect was interesting to ascertain. The authors had referred to non-visible unsoundness, but what was the nature of this? He completely agreed with them that the accurate study of density was assuming great importance, and the contribution was greatly to be welcomed.

Professor Turner agreed with Dr. Rosenhain as to the latter question. The first point requiring to be known was the maximum density of the alloy being investigated. The method of casting was of great importance. Differences in the pouring temperature, in the rate of cooling, and so forth, caused variations. There were voids rather, perhaps, than actual blow-holes, seldom visible without deep etching. Density investigations could serve as a test of the material; if the density were right, the metal was right. In the matter of rolling for closing up the pores he (Professor Turner) agreed with Dr. Rosenhain; it was difficult to know exactly when one had reached the desired end. If there were doubt, it was easy to roll the material a little on the hard side and then to anneal it.

Dr. Moore, referring to Dr. Rosenhain's remarks, said it was true that sound castings could be produced, but it was quite correct to apply to the specimens a slight cold-rolling and then to find out the density. The authors' 9 in. by 2 in. by 1-in. ingots were cold-rolled into 12 in. by 2·3 in. by 0·6 in. slabs, and there was good reason to believe that this had no appreciable effect on the true density; the effect on the density was large only when a larger amount of cold-work than this was carried out.

Dr. Rosenhain here explained that the cavities in the alloys were not voids, but contained gas all of which was not eliminated, and showed by curves the effect of pressure on the gas in the cavities. A small amount of cold-work would not have an appreciable effect in the case he showed, and further explanation was required on the point.

Dr. Smith thought that the difficulty was to know exactly what to take as a datum to start from, and that a cast specimen did not form a satisfactory datum. A common basis should be adopted. He showed slides of illustrating his own work on 70 : 30 brass, rolled to different thicknesses, giving the density at 11 deg. and the density corrected for composition; all the specimens were from the same casting and large variations were seen in the copper content. The densities varied also with the treatment up to a certain extent.

Mr. Genders, in replying, said he knew the ingots could be cast sound; there was no evidence of unsoundness in them, but in order to make quite sure they cold-rolled them slightly, although as far as they knew there were no cavities in the ingots. They had carried out many experiments to ascertain the effect of cold-rolling, and had found that doing it to the amount of a 50 per cent. reduction there was no effect of the order of their experimental error. They had found it quite safe to cold-roll and to make no correction for it. In the case of the ingot containing 99·99 per cent. of copper, for example, they had exactly the same density figure as cast and rolled, and after annealing to equilibrium. A bad impression would be created if it were considered that unsound ingots had been cast, which had been subsequently cold-rolled in order to get rid of the voids supposed to exist in them. The author had not looked into the question of grain size.

### Electrical Resistivity of Copper.

The second paper had reference to "The Effects of certain Elements on the Electrical Resistivity of Copper." It was Mr. A. L. Norbury, who read it in abstract. We reproduced it on page 319 of our last issue.

It gave new data for the electrical resistivities of certain alloys of copper, containing low percentages of each of the following added elements in solid solution: aluminium, silicon, manganese, nickel, zinc, silver and tin. From these results and from those obtained by previous investigators, values for the "increase in the electrical resistivity of copper due to the presence in solid solution of 1·0 atomic per cent. added element" were calculated for each of the added elements. The results so obtained showed that the "atomic effects" were small for elements like silver and gold—which are in the same group as copper in the Periodic Table—and progressively larger as the added elements were further away from copper in the Table. It was suggested, therefore, that the "atomic effects" were large or small according as the "affinity" between atoms of solvent and solute was large or small.

Professor F. C. Thompson queried the figure for silver—17—in the author's diagram, Fig. 2, under group 1, whilst Professor Turner asked why if cadmium and zinc added to copper gave the same effect, cadmium was used and not zinc. Mr. Norbury replied that cadmium had a relatively larger hardening effect.

### The Density of Rhodium.

The third paper, by Sir Thomas Kirke Rose, who read it to the meeting, dealt with "The Density of Rhodium."

It stated that two specimens of rhodium were prepared by Messrs. Johnson & Matthey for the purposes of the investigation, one being forged up from sponge and annealed but not melted, and the other melted from sponge in the oxyhydrogen blowpipe and forged while hot. The rhodium sponge was chemically pure. The density of the melted specimen was 12·47 in vacuo at 0 deg./4 deg., but the other specimen was evidently not free from internal cavities as its density was only 12·22. Previous determinations by other observers had given 12·1 to 12·6, but were unsatisfactory owing to various causes.

Dr. Rosenhain said he had himself made experiments on rhodium and asked whether the author had compared his results with X-ray data.

Professor Desch stated he had been struck with the experimental difficulties which surrounded the accurate determination of density figures, and this applied also to the former paper on the density of brasses. One point of great importance to be noted was that the metals were not pure but retained a large quantity of gas, which was present in minute cavities. Some of these were seen under the microscope and others were not. When the gas was removed by melting under a vacuum the metal gave better density results. He agreed that X-ray examination was of great value in the case of pure metals, but was not so sure in that of alloys.

Mr. A. J. Webb said he had prepared some of the rhodium dealt with. The melted specimen after the density had been taken was carefully examined, and holes could not be seen; the cracks that existed were very slight. The Brinell hardness of the two

specimens was taken; that for the melted specimen was smaller than that for the unmelted, forged one. Oxygen was always absorbed, and he had melted under hydrogen; melting had to be done in lime, but the metal was very hollow and pasty. He was continuing the experiments.

ALUMINIUM-ZINC SYSTEM.

The last paper taken was "On the Equilibrium Diagram of the Aluminium-Zinc System," by Professor Tomimatu Isihara. It was read in abstract by Dr. Marie Gayler. The paper gave the results of an investigation on the equilibrium diagram in question, the research leading up to it having been undertaken by means of the electic-resistance method. Microscopical investigation, the dilatometric method, and X-ray analysis were also resorted to.

Dr. Gayler said that Dr. Hanson and herself were glad to have in the paper a confirmation of their own work (see ENGINEERING, vol. cxiii, pages 319, 538, 666). The electric conductivity method was an extremely good one to determine the diagram, but she did not think it had been used to its fullest advantage. The author had said that for the accurate determination of the solidus, solubility lines and other transformation points in solid phases, the specimens in the form of a rod were made by casting them in an iron mould; to make their structures uniform they were annealed at a suitable temperature for 9 or 12 hours, after once being heated to a high temperature near the solidus. Dr. Gayley stated that if the author was going to determine a cooling curve she did not see the advantage of the treatment here referred to.

Dr. Rosenhain said it was interesting to find that in other countries, by using different methods, the results were the same as those obtained here. The author's work confirmed the work done in this country, but the Hanson-Gayler diagram was a more simple one than the author's.

The other papers in the list were taken as read. All the authors received the thanks of the meeting for their contributions. The usual vote of thanks to the Institution of Mechanical Engineers for the loan of their premises terminated the proceedings.

## A NEW SEPARATELY EXCITED SYNCHRONOUS INDUCTION MOTOR.

By VAL A. FYNN, M.I.E.E., Fel. A.I.E.E.

(*Concluded from page* 283.)

To produce a strictly unidirectional and pulsating synchronising torque the armature of the exciter must be so keyed on the shaft 6 that the exciter flux $f'$ is displaced by an angle $d = 90$ deg. from the brush axis when the axis of the secondary motor winding 9 is displaced by an angle $c = 90$ deg. from the revolving motor flux F', as shown in Fig. 13. After synchronisation the synchronously revolving winding 9 will then be continuously subjected to the maximum unidirectional brush voltage provided it continues to be displaced by $c = 90$ deg. from the synchronously revolving resultant motor magnetisation R. But a displacement of 90 electrical degrees between F and R just about corresponds to the angular relation in which these magnetisations revolve under maximum synchronous load conditions. Upon a reduction in load the secondary accelerates momentarily, reducing the angle $c$ perhaps to the value shown in Fig. 14. This momentary departure from synchronism moves $f'$ by a corresponding amount, reducing $d$ and therefore lowering the unidirectional brush voltage. At no load F nearly coincides with R and $d$ is very small. This means that if all adjustments are made to secure a strictly unidirectional synchronising torque and not changed after synchronisation, the exciting voltage during synchronous operation will vary from a very small value at no load to its maximum value at maximum synchronous load. Fig. 15 illustrates these conditions, showing how the mechanical transmission of the acceleration or deceleration of the motor secondary to the armature of the exciter affects the space relation $c$ of F and R and the magnitude of F for the adjustment in question. The locus for the vector F is L, a circle about point 8 having a diameter equal to $F_{max}$. For this setting, and according to Fig. 13, F is a maximum when it lags 90 deg. behind F' or R, at which time $f'$ is at right angles to the brush axis. In Fig. 15 the brush axis is shown as coinciding with that of F' which makes $f'$ and F coaxial at all times and simplifies the figure. The direction of F depends on the direction of $e_1$, which can be determined from Figs. 8, 9 or 10. The heavily lined portion of the circle L from point 3 to the origin O represents the theoretical range of the useful values of F and is the graph of the exciting characteristic of the motor.

*Fig. 13.*

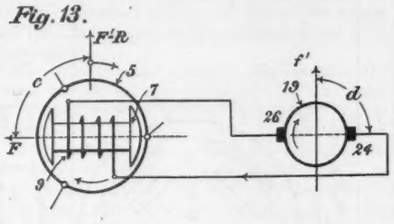



*Fig. 14.*

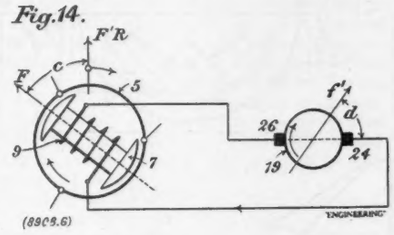



*Fig. 15.*

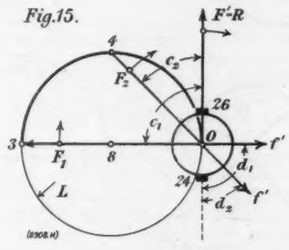



*Fig. 16.*

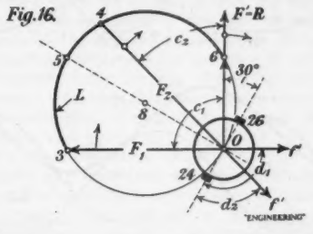



*Fig. 17.*

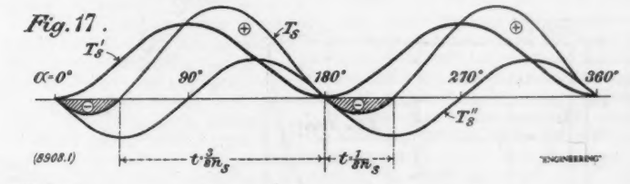
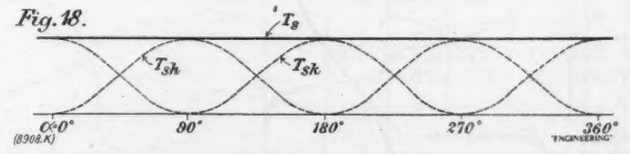



*Fig. 18.*




The exciting characteristic of Fig. 15 may not yield the desired power factor or the desired "compounding" characteristic; to change it while retaining a strictly unidirectional synchronizing torque it is necessary to make a readjustment after synchronism is reached. The characteristic may, for instance, be very readily modified to a very great extent by displacing the exciter brushes or by changing the phase of the polyphase voltages impressed on the exciter. In Fig. 16 the exciter brushes have been moved 30 deg. in the direction of rotation of the secondary. This results in an exciting characteristic the graph of which is the heavily lined part of the circle L located between the points 3 and 6, the maximum excitation has been moved from point 3 to point 5. The characteristic of Fig. 16 is more in accordance with practical requirements. Any change of this nature, however, also means a change in the configuration of the synchronising torque, and the question naturally arises whether or not a compromise brush position can be found which will give satisfactory synchronising and compounding characteristics. This involves the question as to how far one may depart from a strictly unidirectional synchronising torque without material sacrifice in synchronising and asynchronous overload performance.

Let it be supposed that the exciter brushes in Fig. 13 are displaced by as much as 45 electrical degrees, say in the direction of rotation of 19. In such case the winding 9 may be decomposed ihto two windings displaced by 90 electrical degrees and each having 70·7 per cent. of the turns of the winding 9. One of these windings must be coaxial with the axis of the exciter brushes, the other must be at right angles to it. The first then yields a strictly unidirectional and pulsating synchronising torque $T'_s$ with an amplitude equal to 70·7 per cent. of that secured with the setting of Fig. 13. The second produces a synchronising torque $T''_s$ of double slip frequency with equal positive and negative maxima of half the amplitude of the first. The resultant synchronising torque $T_s$ has positive waves, lasting three times as long as its negative waves and the amplitude of the latter is but some 17·13 per cent. of the amplitude of the former as clearly shown in Fig. 17. Under these extreme conditions the resultant synchronising torque is still substantially unidirectional and its configuration is not such as to seriously affect synchronisation or non-synchronous overload conditions. As a matter of fact, a much smaller brush displacement yields a most satisfactory compounding together with a perfectly satisfactory synchronising performance. Thus for a 20 deg. brush displacement in Fig. 13 the maximum excitation is three times as large as the no-load excitation, which is an ample difference for a satisfactory compounding characteristic, and the synchronising torque is all but strictly unidirectional. For a 20 degree brush displacement the positive wave of the resultant synchronising torque lasts eight times as long as the negative, and the amplitude of the latter is but 3·1 per cent. of the former.

Going back to Fig. 5, let it now be assumed that the windings 9 and 10 on the secondary are both available, together with the resistances 33 and 36. In such case it is possible to dispense with the squirrel cage or its equivalent. The motor is then started by suitably adjusting the resistances 33, 34 and allowing the polyphase induction-motor-torque-producing currents generated in 9 and 10 to close over the brushes 24, 25 and the exciter winding 19, simply readjusting the resistances 33, 34 as synchronism is approached. Under these conditions, the commutator of the exciter must carry the secondary starting and the secondary overload currents, which is mostly undesirable in large machines. The commutator can be freed from the starting currents by closing the windings 9

and 10 over the resistances 35, 36 at starting. Automatically to free it sufficiently from secondary overload currents, appearing after the motor falls out of synchronism, it is necessary to fall back on the squirrel cage 8 or its equivalent.

When two displaced windings such as 9 and 10 are used on the secondary and connected in parallel to the exciter brushes as in Fig. 5, then the axis of the resultant magnetisation F, due to these two windings, is determined by the magnitude of the individual magnetisations $h$ and $k$ produced by the windings 9 and 10, respectively. When these individual magnetisations are equal the resultant F falls half way between the two, as shown in Fig. 5. The individual magnetisations are controlled by the resistances 33 and 34, and this supplies another ready means for adjusting the configuration of the synchronising torque or the compounding characteristic. Both can be adjusted by moving the armature of the exciter about the shaft 6 or by displacing the points of connection of the slip rings to the winding 19, or by displacing the brushes 24, 26. The same thing is achieved by displacing F with respect to the secondary 7 by means of the resistances 33, 34.

While a substantially unidirectional synchronising torque in no way interferes with the asynchronous overload capacity of a synchronous induction motor, yet the presence of this torque, the amplitude of which varies but little within asynchronous motor slip speeds, does cause the speed of the motor to vary periodically in an effort to balance supply and demand of torque. This leads to an uneasy running which is often objectionable. To overcome this last difficulty the writer conceived the idea of producing a *constant polyphase* instead of a single phase unidirectional and pulsating synchronising torque. This is achieved by producing two or more single-phase unidirectional and pulsating synchronizing torques and properly spacing their maxima as to time. Fig. 18 shows how two equal unidirectional pulsating torques $T_{sh}$ and $T_{sk}$ in phase quadrature combine into a resultant polyphase and constant synchronising torque $T_s$.

In order to produce two unidirectional and pulsating synchronising torques in phase quadrature it is necessary to dispose of suitably displaced voltages of slip frequency. These are secured in the arrangement shown in Fig. 19 by adding a second pair of brushes 23, 25 to the exciter and displacing them by 90 electrical degrees from the first set 24, 26. In motor Form 4, shown in Fig. 19, the exciter slip rings are connected to the supply through the variable ratio transformers 40, 41, 42. The winding 9 is connected to the exciter brushes 24, 26 through the adjustable resistance 34, and is shunted by the adjustable resistance 35. The winding 10 is connected to the exciter brushes 23, 25, through the adjustable resistance 33, and is shunted by the adjustable resistance 36. The switch 80 is arranged to connect slip ring 11 either to brush 25 or to slip ring 16 and the adjustable resistance 81 bridges the slip rings 12 and 15.

*Fig. 19.*

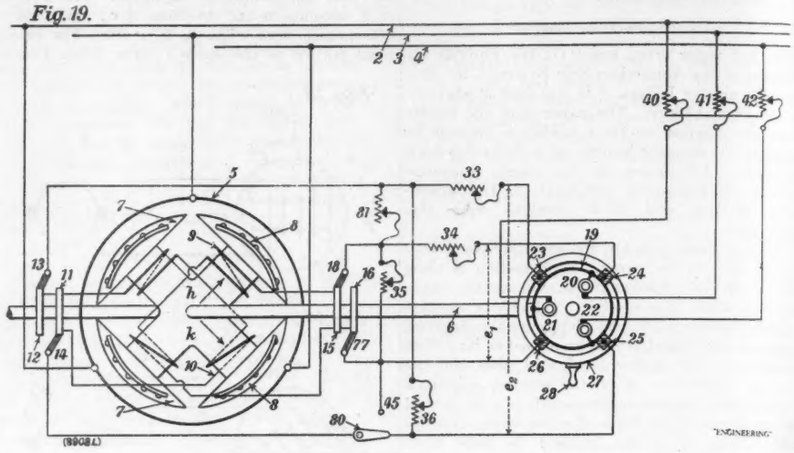



*Fig. 20.*

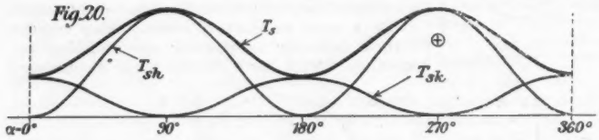



*Fig. 22.*

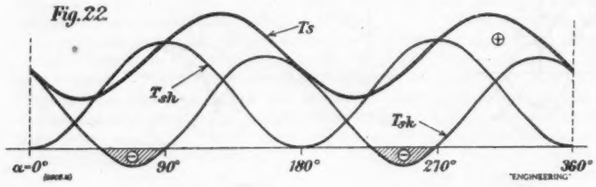



*Fig. 21.*

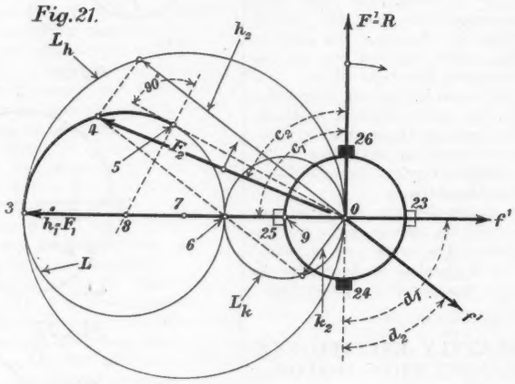



*Fig. 24.*

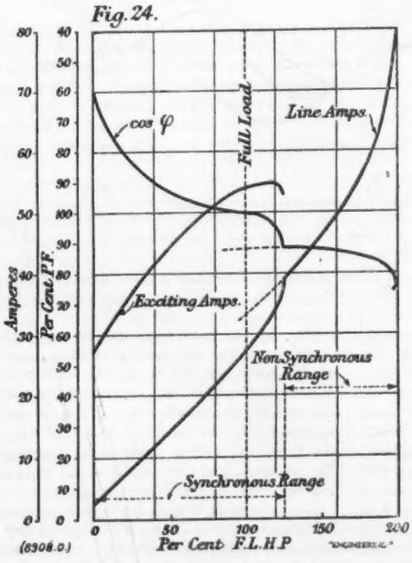
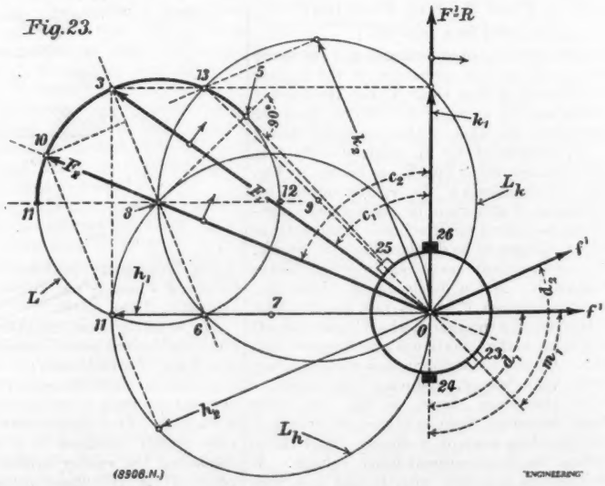



*Fig. 23.*




In operating Form 4, one proceeds in one of the several ways explained in connection with Form 3 until synchronism is reached. A squirrel cage 8 or its equivalent may be used at starting or the starting currents may be allowed to close over the exciter brushes or over the resistances 35, 36. At synchronism, switch 80 stands in the position shown and the resistances 35, 36 and 81 are on open circuit. A unidirectional voltage appears at each set of exciter brushes. Whenever the secondary 7 of the motor momentarily departs from synchronism in an attempt to adjust its position to the existing torque demand, the value

of these brush voltages changes, one increases and the other decreases. Because of the quadrature relation between the two brush sets the voltage at one varies as sin $d$, that at the other as cos $d$, where $d$ is the angle shown in Fig. 13, and not only does the total magnetisation F produced by 9 and 10 under the influence of these brush voltages remain constant at synchronism regardless of any change in the position of the rotor 7 brought about by momentary acceleration or deceleration, but the axis of this magnetisation retains a constant angular displacement $c$ with respect to the resultant revolving motor magnetisation R or $F^1$, irrespective of the rotor speed, which all results in a very interesting situation.

Because the magnitude of the unidirectional magnetisation on the secondary remains constant no automatic compounding results, and the motor speed may rise above the synchronous because $c$ remains constant. If the constant polyphase synchronising torque is equal to the torque demanded by the load, the motor will reach synchronism and continue to run synchronously, but any change in the torque demand will cause it to change its speed because nothing but a change in speed will change the magnitude of the resultant ampere-turns along that axis of the secondary which is displaced by 90 electrical degrees from the axis of the resultant motor magnetisation. If the motor speed drops below synchronism the voltage generated in the secondary windings 9 and 10 by F′ will add to the said secondary ampere-turns, thus increasing the motor torque. At super-synchronous speeds the direction of the generated voltages is reversed and a reduction of the secondary ampere-turns follows and is accompanied by a reduction in motor torque. If synchronism is not to be exceeded, Form 4 cannot be used for motors subject to varying loads without certain precautions or a reorganisation of the circuits.

The foregoing operating characteristics are often undesirable, and it is consequently of importance to point out that they can be readily modified in a number of ways. For instance, the ohms per volt in the circuit of one set of exciter brushes may be made to differ from the ohms per volt in the other brush circuit, or the angular relation of the polyphase arrangement of exciter brushes can be made to differ from the angular relation of those secondary windings on the motor which are connected to the exciter brushes, or both of these changes may be made concurrently and either before or after synchronism has been reached.

Suppose that in Fig. 19 the resistances 33 and 34 are so adjusted that the ratio of the maximum conduced ampere-turns in the secondary windings 9 and 10 is as 8 to 3.

In so far as resultant synchronising torque is concerned, all necessary information is given by Fig. 20. As compared with Fig. 18 it is only necessary to correspondingly change the ratio of the maximum amplitudes of the component torques $T_{sh}$ and $T_{sk}$. The resultant synchronising torque $T_s$ is unidirectional but not constant, its magnitude variations are, however, considerably smaller than those of the torque in Fig. 11, which is obtainable with motor Form 3.

The excitation characteristic for an unequal number of maximum conduced ampere-turns $h$ and $k$ in the windings 9 and 10 of motor Form 4 is shown by the diagram of Fig. 21, which follows the lines of that of Fig. 15. When $h_{max.}$ differs from $k_{max.}$ the momentary asynchronous displacements of the rotor not only change the angle $d$ of Fig. 13, but also alter the magnitude of F, which is the resultant of $h$ and $k$, and its angular space relation $c$ with respect to R. This means that the motor will operate synchronously at a plurality of loads and will have a compounding characteristic. With changing load the ends of the vectors $h$ and $k$ of Fig. 21 move along the circles $L_h$ and $L_k$, the locus for the vector F is the circle L. The minimum torque at which the motor will run without exceeding synchronism is determined by the secondary unidirectional magnetisation represented by the vector 0–6, the theoretical maximum synchronous torque corresponds to the secondary magnetisation measured by the vector 0–3. The more desirable part of the exciting characteristic lies between points 3 and 5. The diameter 0–3 of $L_h$ is determined as to location and magnitude when $f'$ is at right angles to the axis of the brushes 24, 26. Similarly, the diameter 0–6 of $L_k$ is determined when $f'$ is at right angles to the axis of the brushes 23, 25. The diameter of L is the distance between any two values of F corresponding to quadrature positions of $f'$. When $f'$ is perpendicular to 24, 26 then $h = F$, the line 3–6 is therefore a diameter of L.

Suppose now that instead of changing the ratio of the maximum conduced ampere-turns in 9 and 10 by changing the resistance of their circuits, the brushes 23, 25 in Fig. 19 are displaced by 45 deg. in the direction of rotation of the secondary of the motor, while the displacement of the windings 9 and 10 is not changed.

Under these changed conditions the circuit of the brushes 24, 26 will be responsible for the same strictly unidirectional synchronising torque $T_{sh}$ as previously, but the circuit comprising the brushes 23, 25 now produces a torque of the configuration shown by $T_s$ of Fig. 17. The resultant torque $T_s$ in this case is shown in Fig. 22, which speaks for itself.

The effect of a 45 deg. displacement of the brushes 23, 25 on the exciting characteristic of motor, Form 4, is shown in Fig. 23. The diameter for $L_h$ is fixed by the value of $h$ when $f'$ is perpendicular to 24, 26; that for $L_k$ is fixed by the value of $k$ when $f'$ is perpendicular to 23, 25. When $f'$ is coaxial with 24, 26 the resultant magnetisation F equals 0-6, which is the value of $k$ for that position of $f'$, after $f'$ has moved clockwise through 90 deg. F has the value $F_1$ and equals 0-3. One diameter of L is therefore 3-6.

The voltage at the brushes 24, 26 varies as sin $d$, the voltage at the brushes 23, 25 varies as sin $m$, the two angles being measured as shown in Fig. 23. The minimum torque at which the motor will run without exceeding synchronism is determined by the secondary unidirectional magnetisation represented by the vector 0-12. The more desirable compounding characteristic lies between point 5 and the point 11 which is that of maximum synchronous output.

These two examples show what can be accomplished in so far as range of synchronous operation and compounding characteristic is concerned, by changing the ohms per volt for the several secondary motor circuits connected to the exciter, or by giving the exciter brushes a displacement which does not correspond to that of the secondary motor circuits to which they are connected. The full advantage of a constant polyphase synchronising torque can, however, be secured in combination with practically any desired compounding characteristic, and while positively avoiding supersynchronous speeds by disconnecting the second pair of exciter brushes as soon as synchronism is reached and reconnecting them when the motor lapses into asynchronism. This can be done in Fig. 19 by means of switch 80. If it is desired to utilise winding 10 during synchronous operation, then after switch 80 has been placed on contact 45, the slip rings 12 and 15 should be interconnected by means of the adjustable resistance 81, thus connecting windings 9 and 10 in parallel to the exciter brushes 24, 26. These or corresponding changes can readily be carried out automatically as will appear from another paper written by the author.

Fig. 24 shows the character of the performance curves obtainable with the new motor of either form. The machine of Fig. 24 is so rated that the maximum synchronous load is 62 per cent. and the synchronous full load is 50 per cent. of the maximum asynchronous load. This rating allows of a 12 per cent. drop in line voltage before the fully loaded motor lapses into asynchronism. Where better line voltage regulation is assured the rating can be raised. Thus, if the voltage drop does not exceed 6 per cent. the synchronous full load of the motor of Fig. 24 can be raised to 55 per cent. of the maximum asynchronous load which still leaves an ample overload capacity of 82 per cent. and under normal operating conditions assures a synchronous speed at all loads up to and including full load. These new motors must be amply ventilated if full advantage is to be taken of their possibilities in the way of utilisation of active material.

An exciter without secondary excitation takes lagging currents from the line, the simplest way to compensate for these is to cause the motor it serves to take corresponding leading currents at all loads. The automatic compounding feature here described can be readily made to satisfy this requirement and at loads less then full load the power factor of the combination will usually be leading notwithstanding the lagging currents taken by the exciter. These currents can be eliminated if desired by providing the exciter with unidirectional excitation independent of that furnished by its polyphase armature. To this end an exciting winding can, for instance, be disposed on the secondary of the exciter and connected to the exciter brushes. If used, it will affect the compounding characteristic and must be located, dimensioned and controlled with this fact in view.

*Conclusions.*—The new motor makes it possible to build a separately excited synchronous induction motor of at least the same weight efficiency as the corresponding slip ring induction motor of like conversion efficiency, but such a machine requires an exciter which, however, is lighter than the exciter of the corresponding straight synchronous motor with equal overload capacity.

These advantages are secured by producing a pulsating synchronising torque substantially or strictly unidirectional or a constant synchronising torque, and building an automatic compounding feature into the machine or placing the unidirectional excitation in the control of an automatic regulator. Either combination permits the motor to be built with an air gap of standard induction motor length and results: (1) In a starting performance equal to that of the best induction motor. (2) A synchronising torque equal to the maximum synchronous torque, which means that the motor will slip back into synchronism with perfect smoothness so soon as the demand for a torque in excess of the maximum synchronous torque has subsided. (3) Freedom from hunting during the synchronising period. (4) A satisfactory automatic compounding characteristic, maintaining at least unity power factor and preventing the motor from taking an objectionably large leading current component under any operating conditions including no-load. (5) The possibility of making the maximum synchronous torque equal to more than half the maximum non-synchronous torque, and of so rating the motor that its full torque is only some few per cent. below the maximum synchronous torque, just enough to take care of the usual line voltage fluctuations at full load without lapsing into asychrononism. (6) The possibility of operating the machine asynchronously under overloads, thereby fully utilising the active material in use and reaping the advantage of the cushioning effect of the non-synchronous induction motor at least during the most trying operating periods.

## THE DENNY-EDGECOMBE DIRECT VISION TORSIONMETER.

MEASUREMENT of power by means of an instrument designed to measure the angle of twist per unit length of a shaft under stress is a comparatively old idea, and many investigators have applied themselves to its development. With the advent of the steam turbine, a solution of the problem, which hitherto had been largely of academic interest, became a practical engineering necessity, and when Messrs. Denny, of Dumbarton, in the year 1900 contracted to build the first commercial turbine-driven vessel, attempts were at once made to construct a practical torsionmeter suited to the conditions of marine engineering. Contemporaneously, other workers were attacking the same problem and, in various ways, more or less successful solutions were arrived at. It is not proposed to recapitulate these efforts, but an examination of the various types that have made their appearance results immediately in a broad classification under the two heads (*a*) electrical, and (*b*) non-electrical.

The problem to be solved may be stated in a few words. It is required to measure the torsion (usually expressed in degrees) in a known length, say, 5 ft., of a rotating shaft, by apparatus capable of readily distinguishing and consistently indicating angles of twist of about 12 seconds of arc, or, say, 0·0033 deg. Also, it is required that this measurement be determinable for all angular positions of the shaft, or, alternatively, that where cyclic variations occur, it represent the average torsion throughout the cycle. The problem to be solved is thus a purely mechanical one, and where electrical devices are introduced, they serve merely as means to an end. They are not essential to

the solution of the problem. It is thus a matter of no little surprise that by far the greater number of designs that have appeared are of the electrical type, and it is significant that Sir Archibald Denny, and Mr. F. T. Edgecombe, whose work in connection with torsionmeters is well known, have now returned to a purely mechanical device as the most suitable means of meeting the requirements involved.

Of electrical types, that designed by Mr. E. B. Moullin, and manufactured by the Cambridge Instrument Company was described and illustrated in the issue of ENGINEERING, June 13, 1924. As may be remembered, the basic principle of this device is the variation of the length of the air gap in the magnetic circuit of an electro-magnet or choke-coil, due to the winding on an electro-magnet (or transformer) situated at the control station. The air-gap of the latter is adjusted until exact balance occurs, and the measurement of torsion is determined by the amount of adjustment necessary at the stationary electro-magnet to establish true balance. The apparatus involves a motor-interrupter, slip rings, brushes, a current indicator, and some very pretty micrometric adjustment devices for varying the air-gap of the second electro-magnet, in order to obtain the necessary electrical balance.

The new non-electrical Denny-Edgecombe torsionmeter is manufactured by Messrs. Kelvin Bottomley and Baird, Limited, of Glasgow, who have long specialised on torsionmeter constructions.

The same firm have, since 1913, manufactured the Denny-Edgecombe averaging torsionmeter, an instrument of the electro-mechanical variety which has thus had a long run, and done yeoman service. It has been installed on approximately 200 ships, and is to be found in the mercantile and naval vessels of all nationalities that make any pretence to maritime activities.

Messrs. Denny have excellent opportunities of making direct comparison between the shaft horse-power as obtained from torsionmeters during trials on the measured mile, and the shaft horse-power predicted from tests with ship-models run in association with model propellers in their experimental tank. Thus, the combination of Messrs. Denny-Edgecombe with Messrs. Kelvin Bottomley & Baird, Limited, in torsionmeter matters is an exceptionally strong one, and their considered judgment, after nearly a quarter of a century's experience of ship-design, ship-construction, and torsion tests, certainly merits careful attention. In the discussion of a paper read before the Institution of Naval Architects last year, a number of trial results were published, some of which are reproduced in the Table opposite, to illustrate the agreement between the shaft horse-powers obtained by Denny-Edgecombe torsionmeters on the measured mile and the shaft horse-powers predicted from models in the experimental tank.

The comparison shown in the last column, which gives the percentage by which the shaft horse-powers obtained from Denny-Edgecombe torsionmeters, on the ships, varies from the shaft horse-power obtained directly from model propellers working in proper position behind models of the ships fitted with shaft bosses and rudders. The shaft horse-power for the last vessel in the table which was the motorship Scottish Borderer, was taken both with the averaging torsionmeter and with the new direct vision torsionmeter, the results being in perfect agreement.

The agreement is remarkable as it stands, but the real relation between the shaft horse-power for ship and model is much closer than these figures indicate. The powers from model experiments are for absolutely uniform conditions, that is clean paraffin surface, constant temperature of water, still air and no waves, and absolutely straight course independent of rudder effects. Such a standard combination of circumstances is impossible of attainment on ship trials; clean painted ships are by no means of uniform surface quality, sea temperature varies (but can be corrected for), while errors due to weather and use of the rudder are indeterminate, but are probably not very serious in most cases. There is good reason to believe that the greater part of the variation is due to differences of paint surface on the hull. Take, for instance, ships numbered 11, 12, 13, 14 in the Table. These were sister ships, compared at the same speeds; when No. 11 was tried

*Fig. 1.*

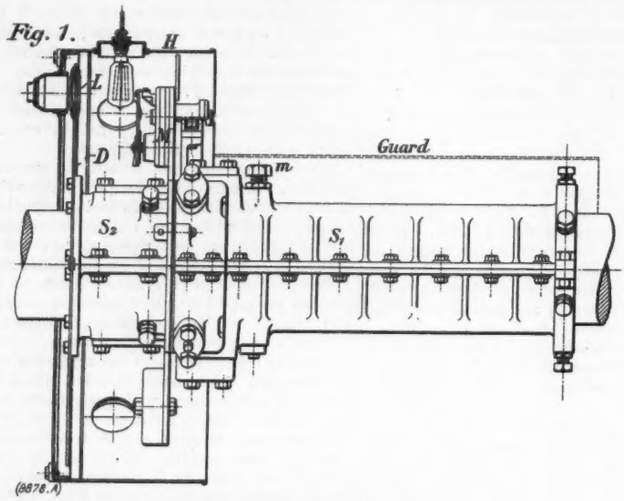



*Fig. 2.*

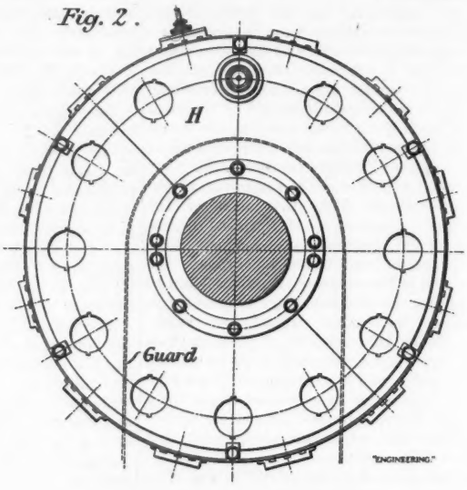


FIG. 3. VIEW ILLUSTRATING OPTICAL PRINCIPLE OF TORSIONMETER.

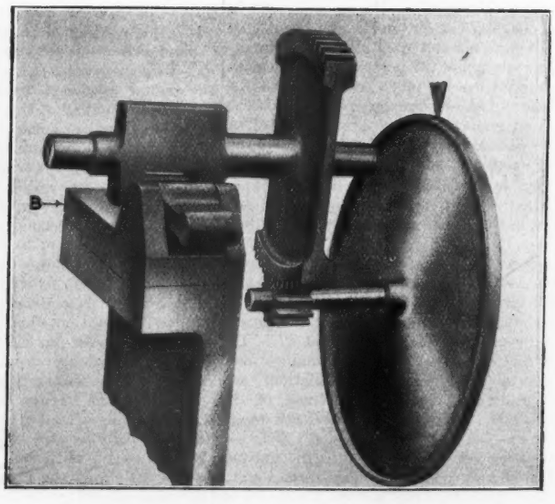



FIG. 4. MOTION MAGNIFYING GEAR.

twist occurring in a section of shaft of known length. The change of magnetic reluctance is utilised to provide a measure of the twist and of the horse-power transmitted. The apparatus includes a motor-alternator for supplying the electro-magnets, a delicate alternating-current indicator, a set of slip-rings and brushes for supplying current for the electro-magnets, and so forth. The article referred to also described the use of such devices as oscillographs and photographic films for the purpose of recording cyclic variations of torque.

Since that article appeared, another electrical torsionmeter has been introduced by Messrs. Siemens Brothers and Co., Limited. This instrument was described in our issue of February 13. In this apparatus again, the reluctance of the air-path of a small electro-magnet (or transformer) is made to depend upon the torsion in the shaft, but instead of measuring directly the current flowing in the circuit, the E.M.F. induced in a secondary winding of the rotating electro-magnet is balanced against the E.M.F. of a similar

the paint surface on the hull was hard and dry. With Nos. 12 and 13 there was no opportunity for obtaining such a good surface, largely owing to weather conditions, and the speed results were correspondingly worse. Special precautions were taken, in view of this, when No. 14 was ready for trial, and a hard dry surface was secured, with the result that the speed and power relations of No. 11 were not only repeated but slightly improved upon. This is rather a good illustration because the wind and wave conditions were practically the same on all the trials, the only important change being in the paint surface. Many other cases could be cited confirming this view, and if such possibilities are borne in mind, the agreement between shaft horse-power read from these torsionmeters and predicted from model experiments is notable indeed. It may be remarked, in passing, that the revolutions of the propellers of the ships were predicted even more closely than the shaft horse-powers.

Experience of the above character, gathered throughout a period of many years, has demonstrated that there are certain fundamental qualities which a torsionmeter must have if it is to be relied upon. (1) It must be supported upon the shaft. If any part of the measuring apparatus be attached to the hull of the ship, there is almost certain to be error because the relative positions of the shaft and hull change under the stresses developed when transmitting power. There is elongation of the shaft by expansion or *vice versa*; there is often change in the fore-and-aft position when a ship is going astern as compared with the position when going ahead, caused by the cumulative effect of small extensions at the coupling bolts; and there is the error caused by temporary deformation of the hull under stress. All, or any of these may be small, but they may also be additive and fatal to accuracy when such a small measurement as the angle of torsion has to be made. (2) It must measure either the cyclic variation, or else by averaging methods, the mean torsion during the revolution, and not make the unwarranted assumption that there is no variation of torsion when the prime mover is a steam turbine. There are two ends to a marine shaft, and while there may be no variations of torque from the turbine end, there are often variations of resistance of a large order at the propeller end, especially if the vessel be a single-screw ship with low revolutions and reduction gearing.

It follows from the foregoing that a spot-reading meter, that is, one which registers the torsion only at one or perhaps two positions during the revolution, is useless for steam reciprocating or oil-engined vessels; but it is necessary, even at this date, to emphasise the fact that it is bad practice to use such a meter even on a turbine shaft, since it assumes uniformity of torsion in all cases. (3) The instrument must be, at all costs, robust and suited to marine engineering conditions as they exist in the propeller-shaft tunnel. (4) A very desirable, although not perhaps a fundamental requirement, is adaptability to shafts of different diameters. A torsionmeter which can readily be adapted to shafts of different sizes over a wide range, ought to form part of the permanent testing equipment of every marine-engine builder.

The figures given in the table, which are merely exemplary of a great many others that could be quoted, are sufficient evidence that the Denny-Edgecombe averaging torsionmeter of the electro-mechanical type is capable of giving exceptionally good and reliable results in the hands of persons accustomed to these instruments. The makers, however, have felt that electrical instruments and small parts are liable to trouble when located permanently in a shaft tunnel, where they are subject to large changes of temperature, and heavy condensation, to say nothing of mechanical injury and abuse and other adverse conditions, and the object of the designers in producing the latest non-electrical pattern of meter has been to replace the purely electrical features of the earlier pattern by a simpler device, leaving the salient features otherwise unchanged. Figs. 1 and 2, on page 346, show the general arrangement of the torsionmeter. It comprises the usual sleeve $S_1$ carried co-axially on the shaft, one end (the right-hand end in Fig. 1) being rigidly fixed to the shaft and the other free to move in spigot and socket relation with a second short sleeve or "stump" $S_2$ also rigidly clamped to the shaft. Both sleeve and stump are provided with radial arms, one of the arms on the stump carrying a motion-multiplying gear-box M with scale and index finger. This gearing connects with the radial arm of the sleeve by means of a stout balanced link so that any relative angular movement of the radial arms is indicated in a magnified measure by the movement of the index finger over the scale.

Up to this point the torsionmeter is identical in principle with its predecessor, the electro-mechanical averaging meter. The departure, however, comes in at this point. Formerly, in order that the position of the index finger on the scale might be read during the rotation of the shaft, the finger was arranged to move a contact over the face of a rheostat, thus varying the resistance of an electric circuit in such a way that the pointer of an indicating instrument, included in the circuit, deflected correspondingly with the index finger of the gear-box M. This involved the use of accumulator cells as a source of electric supply, a specially arranged ammeter as an indicating instrument, slip rings on the torsionmeter with the necessary brushes, and a rheostat device operated by the index finger of the motion-magnifying gear-box.

By the employment of a somewhat novel optical device, it has now become possible entirely to eliminate all this electrical apparatus and to read the position of the index finger on its scale during rotation. To this end, the stump carries a disc D which supports a lens L in axial register with the index finger and scale of the gear-box. The lens may be regarded as an ordinary good reading glass or magnifying lens, located at a distance from the index finger and scale equal to its focal length. The whole is enclosed by a stationary housing H, suitably attached to the framework of the ship, while in the end face of the casing a number of inspection apertures are provided. On looking through any one of the inspection apertures, the index finger is seen to be stationary, and its position against the scale is very readily observed at all speeds, although, of course, the impression on the observer's eye is not continuous.

The optical principle employed here is one of great simplicity and will be understood on reference to Fig. 3. This shows an observer looking down a length of tubing (introduced solely for the purpose of confining his line of sight to a definite direction) through a reading glass on to a small object such as a washer or a small coin about equal in diameter to the aperture of the tube. The reading glass is mounted on a frame which also supports the washer, and the frame, together with the magnifying glass and washer, may be displaced laterally across the line of vision. Now, when this is done, the result noted by the observer is that the washer still appears centrally disposed within the aperture formed by the tube so long as there is any portion of the magnifying glass below the tube. Suppose, for instance, that the magnifying glass is $2\frac{1}{2}$ in. in diameter, then the frame, with the washer, can be shifted backwards and forwards over a range of roughly $2\frac{1}{2}$ in. without any apparent displacement of the washer, as viewed by the observer. In other words, if an object be seen by an observer through a magnifying lens located at its focal length from the object, and if the object and lens move together across the line of sight of the observer, the object will appear to be stationary so long as it is seen through the lens. This is precisely what is done in the torsionmeter. The index finger and the scale, form the object. At a suitable distance in front of the scale, a collimating lens is arranged. Once during each revolution, the lens and object move across the line of sight of the observer as above described, thus the object appears stationary during the whole transit period. Actually, the vision is sharpened considerably by the use of a slot diaphragm between the two components of the lens. The slot is $\frac{1}{8}$ in. or $\frac{1}{4}$ in. wide and is directed radially towards the

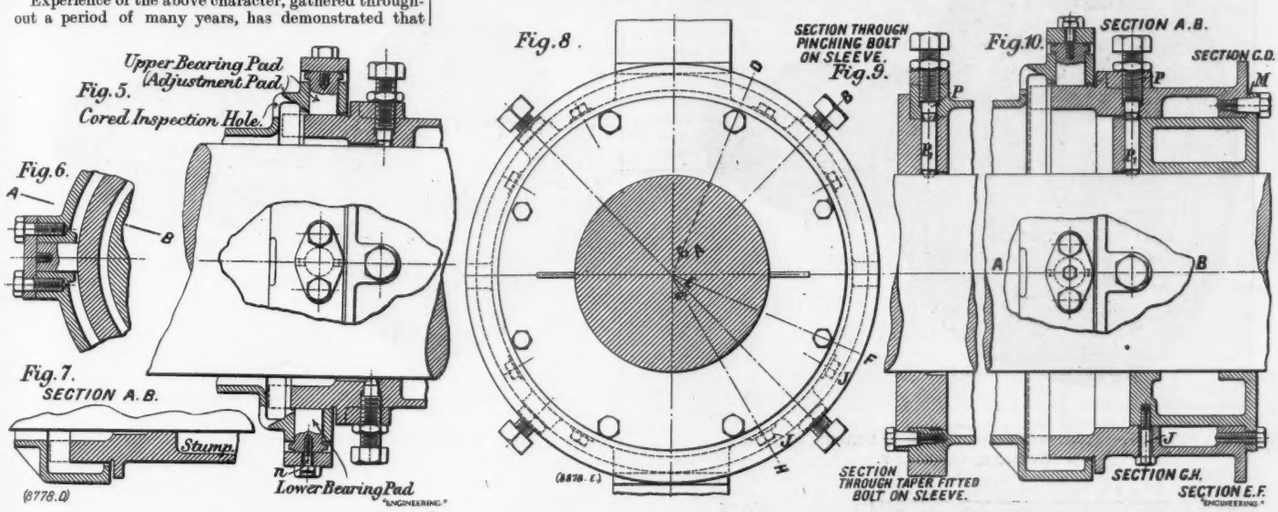



TABLE GIVING COMPARISONS OF MODEL-EXPERIMENT AND TORSIONMETER SHAFT HORSE POWERS.

| Type. | Length in feet. | Moulded Breadth. | Mean Moulded Draught. | Block Co-efficient. | Speed in Knots. | Shaft Horse-power from Torsionmeters related to Shaft Horse-power from Model. |
|---|---|---|---|---|---|---|
| | | ft. in. | | | | |
| (1) T.S. Turbine | 297 | 36 0 | 11·905 | 0·5115 | 20·0 | 2 per cent. greater. |
| (2) T.S. „ | 348 | 42 0 | 9·896 | 0·505 | 23·816 | 8 per cent. less. |
| (3) T.S.S. (Reciprocating) | 195 | 28 0 | 8·88 | 0·499 | 15·58 | 5 per cent. less. |
| (4) T.S. Turbine | 380 | 51 6 | 24·179 | 0·628 | 15·114 | 5 per cent. less. |
| (5) T.S. „ | 380 | 51 6 | 24·179 | 0·628 | 15·114 | 6 per cent. less. |
| (6) T.S. „ | 310 | 40 0 | 11·225 | 0·512 | 20·5 | 7 per cent. greater. |
| (7) Comb. Triple S | 480 | 61 0 | 23·812 | 0·6885 | 16·26 | 1 per cent. greater. |
| (8) T.S.S. (Reciprocating) | 410 | 52 3 | 19·495 | 0·627 | 16·57 | 3 per cent. less. |
| (9) T.S. Turbine | 397 | 52 5 | 16·08 | 0·611 | 14·25 | 3 per cent. less. |
| (10) T.S. „ | 403 | 54 0 | 17·86 | 0·551 | 20·25 | No difference. |
| (11) T.S. „ | 387 | 45 0 | 11·75 | 0·5075 | 25·0 | 3 per cent. less. |
| (12) T.S. „ | 387 | 45 0 | 11·75 | 0·5075 | 25·0 | 1 per cent. greater. |
| (13) T.S. „ | 387 | 45 0 | 11·75 | 0·5075 | 25·0 | 5 per cent. greater. |
| (14) T.S. „ | 387 | 45 0 | 11·75 | 0·5075 | 25·0 | 4 per cent. less. |
| (15) T.S. „ | 390 | 54 0 | 13·897 | 0·498 | 22·5 | 2 per cent. less. |
| (16) T.S. „ | 348 | 42 0 | 9·896 | 0·505 | 23·53 | 2 per cent. less. |
| (17) T.S. Motorship | 425 | 56 8 | 26·104 | 0·793 | 11·483 | 1 per cent. greater. |

centre of the shaft. The scale is illuminated by a lamp fitted into one of a number of suitable apertures in the stationary housing. The eyepiece shown does not, as a rule, contain any lens, its object being simply to locate and centre the observer's eye.

The motion-magnifying gear box is of a very strong construction. The principal components are well illustrated in Fig. 4. B is the link bracket which is securely attached to the radial arm projecting from the sleeve. The bracket carries a link which connects to a crank on the main spindle of the motion-magnifying-gear. Solid with the crank is a portion of a large diameter toothed wheel, which meshes with a small pinion made in one piece with a spindle, to which is attached an aluminium disc inscribed with a degree scale. The teeth are involute and have a width of $\frac{1}{2}$ in. A very small amount of back lash is allowed which is taken up by a strong clock spring acting upon the secondary spindle (that is, the small pinion spindle). The balanced crank, gear wheel, pinion and scale disc form together the motion-magnifying gear box carried by the radial arm projecting from the sleeve. The robust nature of this portion of the mechanism, which, it may be noted, is the most delicate part of the whole apparatus, is specially worthy of attention. For high speed outfits, the centrifugal force acting upon the crank spindle and main gear wheel unit is quite considerable and special steps for adequate lubrication become necessary. The difficulty is met by the use of a special lubricating grease preparation due to Messrs. Kelvin Bottomley and Baird. This preparation was first developed by them for the purpose of lubricating the valves of their Pneumercator tank-gauge apparatus. Its characteristic is an elastic body which neither runs thin on being heated to a considerable temperature nor becomes too solid at low temperatures, and it appears to be a most suitable lubricating material for the present purpose.

It will readily be understood that the workmanship on these details has to be of the very highest class. All slackness and play in joints, links, &c., must be eliminated; hence the necessity for the exceptionally stiff and solid construction. A new feature in this torsionmeter is the bearing device between the sleeve and the stump where they come together in spigot and socket relation. It is obviously necessary that no restriction impeding relative angular motion between the sleeve and the stump must result, but, at the same time, all lateral motion must be prohibited. It is necessary, therefore, to provide an accurate bearing which will not bind, on the one hand, and will not allow play, on the other. Remembering that both stump and sleeve are split and fitted in halves around a shaft, and are liable to slight distortions, it will be seen that special precautions are necessary to ensure that the bearing of the sleeve upon the stump, as erected on the ship, fulfils the conditions above laid down.

This difficulty is met by providing the sleeve with four radial pockets, into which bearing pads are slid and retained in position by cover plates, as illustrated on Figs. 5 to 7. The bearing pads may be attached to their respective cover plates by means of the screws *n*. The method of manufacture and erection is then as follows:—The bearing pads inserted in the sleeve are turned on the inner faces to the true diameter of the stump on which they are intended to bear. When erecting the torsionmeter on the shaft, the pads in the lower half of the sleeve are left in position while those of the upper half are removed. The upper half sleeve is distinguished by being provided with the screw *m*, Fig. 1, which, on being screwed down bears upon the cylindrical surface of the shaft. The torsionmeter being assembled in other respects, screw *m* is tightened down until it carries the weight of the free end of the sleeve. This end is thus centred for the time being by the two bearing pads in the lower half and the screw *m* in the upper half of the sleeve bearing down upon the shaft. The two bearing pads belonging to the upper half sleeve, detached from their cover plates, are now dropped into their pockets, a cigarette paper having been first placed upon their lower surfaces. The top flat surface of the pad is then worked down by the fitter until it just comes fair with the top plane surface of the pad pocket. This is readily detected by running a straight edge across the surface. When this has been done, the cigarette papers may be removed and the cover plates may be screwed down hard with the certain knowledge that there is no binding between the stump and the sleeve, and, at the same time, no undue play has been permitted. Finally, the centralising screw *m* is withdrawn permanently from the apparatus or screwed back and securely locked in that position. Considerable importance is attached by the makers to this form of bearing. They call attention to the great advantage in enabling the superintendent engineer to check for himself, after the erection of the torsionmeter, whether there is any binding or undue play between the sleeve and the stump. From the description already given, it will be evident that such checking or control can be applied at any time, provided the shaft is stationary, and an examination can be carried through probably well within an hour.

Reference has already been made to the very desirable feature of rendering the torsionmeter adaptable for shafts of largely differing diameters. If this is feasible, it will enable engine builders to equip themselves with standardised torsionmeters as part of their testing plant, with which they can test each power unit as built. Steamship owners, similarly, can transfer torsionmeters from ship to ship for the purpose of making periodical tests of the efficiency of their propelling plants, and the advantage of adaptability in many other directions will be recognised. In this connection it may be mentioned that Messrs. Denny have always had their own torsionmeters of the electro-mechanical type as part of their testing plant, and they have fitted them in the manner above described to each power unit they have constructed. In the design of the new torsionmeter, the desirability of adapting them for use with liners to suit different-sized propeller shafts has been particularly borne in mind. It is a relatively simple matter in the makers' works to fix a liner into a torsionmeter sufficiently rigidly for the purpose in view, but it is not such a simple problem to arrange for the liners to be interchangeable, and the torsionmeter to be adapted to receive liners which may be sent from the makers' works at any time in the future for the purpose of fitting the meter to new shafts. It is to be remembered that there must be no possibility of yield or "give" between the liner and the torsionmeter sleeves, or between the liner and the shaft. It is also to be remembered that the torsionmeter and liners are split, and that the different components are subject to very considerable stresses and liability of distortion owing to the action of the pinching screws gripping the apparatus on the shaft, to centrifugal

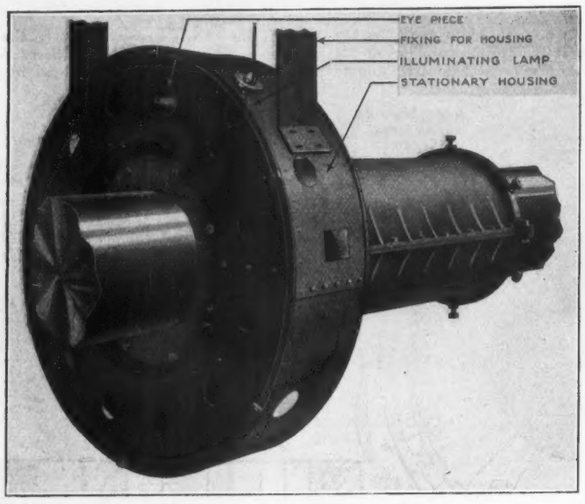



FIG. 11. TORSIONMETER FOR THE SOUTHERN PACIFIC STEAMSHIP COMPANY.

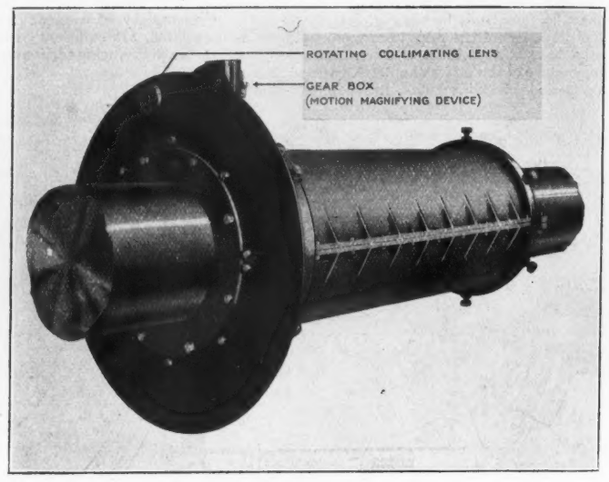



FIG. 12. TORSIONMETER WITH OUTER STATIONARY HOUSING REMOVED.

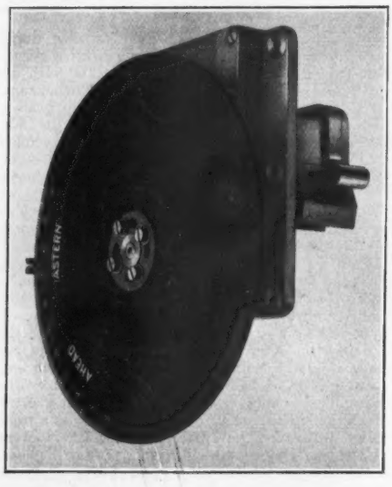


FIG. 13. MOTION-MAGNIFYING GEAR BOX.

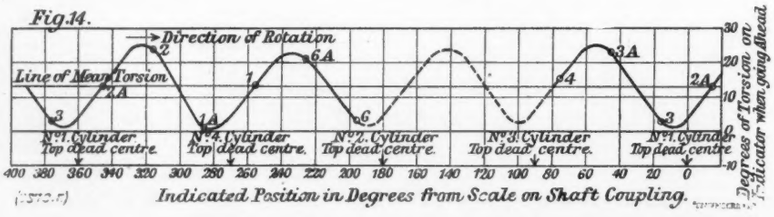


Fig.14.
Direction of Rotation
Line of Mean Torsion
No.1 Cylinder Top dead centre.
No.4 Cylinder Top dead centre.
No.2 Cylinder Top dead centre.
No.3 Cylinder Top dead centre.
No.1 Cylinder Top dead centre.
Indicated Position in Degrees from Scale on Shaft Coupling.
Degrees of Torsion on Indicator when going Ahead.

forces, inertia effects, and so forth. The construction adopted is shown in Figs. 8, 9 and 10. Each liner is cast in one piece, but provision is made when casting for enabling it to be split readily. A parting plate with a specially prepared surface which will not adhere to the metal, is put into the mould, and the metal is cast round it in such a way that, when the liner is to be split, only a small section of the cast metal need be sawn through, after which it comes away in halves, the parting plates falling out.

The liner having been bored and turned accurately, the flange M is jig-drilled for, say, eight bolts, to secure it to the torsionmeter, which is also jig drilled. As a rule, four of the bolts have parallel shanks and are inserted first and drawn up hard. Four intermediate screws have taper shanks. These eight bolts form the drive between the liner and the torsionmeter. The pinching screws P, the object of which is to secure the torsionmeter with the liner to the shaft, are described as broken-jointed screws. The liner is supplied with separate accurately fitting plugs $P_1$, and the sleeve with screws P. Both screws and plugs have hardened, cup-ended lower faces. Thus, $P_1$ bites into the shaft surface, while P bites into the top surface of $P_1$. On either side of each pinching-screw combination P, $P_1$, radial screws J are provided for drawing down the torsionmeter sleeve hard on the liner body and distributing, as between the sleeve and the liner, the distorting stresses caused by the very considerable bursting forces on the sleeve which arise from the pinching screws P, $P_1$. It will be appreciated that, with this design of liner, it is not a difficult matter to remove one and substitute another in a torsionmeter which has already seen a good deal of service, and may, in consequence, have suffered a certain amount of distortion from the various forces to which it has been subjected in its previous history.

Figs. 11 to 13 illustrate a torsionmeter of the type above described, recently supplied to the Southern Pacific Steamship Company, of the United States. The meter was specially constructed for use successively on two ships, one having a 16-in. shaft, while the other had an 18½-in. shaft. Fig. 11 shows the general view of the torsionmeter with the outer stationary housing in place, while Fig. 12 shows the same with the stationary housing removed. In this, the disc carrying the collimating lens is clearly seen, while Fig. 13 further illustrates the motion-magnifying gear-box.

A similar torsionmeter was applied to one of the shafts of the motorship Scottish Borderer, and arrangements were made so that readings could be taken simultaneously by electrical averaging and direct vision. Fig. 14 is a diagram passing through observed points. The arithmetical average of readings gave the same figure for mean torsion as that read from the electrical indicator of the averaging meter, thus checking both systems. The engines were of the four-cylinder, two-cycle, Sulzer type, driving three-bladed propellers, the torsionmeter being situated abaft the flywheel. A reference to this ship (No. 17) in the table on page 347 will show that the shaft horse-power so measured was only 1 per cent. greater than that obtained from model experiments, which in this case were made after the ship trials, the exact ship and propeller conditions being reproduced on model scale as far as possible.

It should be noted that where restriction of space makes it impossible to read all round the shaft a duplex arrangement can be supplied, by which it is possible to obtain all the readings from one side of the shaft, one half of the apertures for viewing the scale facing forward, and the other half facing aft. This is attained by fitting duplicate multiplying gear on the diametrically-opposed arms and lengthening the housing to accommodate a second collimating lens and disc.

## THE PRETORIA MUNICIPAL POWER STATION.

AN interesting example of a modern power station of moderate size, planned as a whole from the first, is furnished by the new station which has been built by the Municipality of Pretoria and which was completed last year. The station, which has a capacity of 10,000 kw., supplies a direct-current distribution network in the centre of the city and also gives a supply to the trams through a converting substation. In addition, the total load is made up by supplies to public-works departments, railway workshops and Government offices. This type of load is not greatly different from that carried by many more or less comparable stations in this country, but, for some reason, conditions in South Africa, which seem to be common to other parts of the Empire and to some foreign countries, have resulted in a load factor of 40 per cent. for the station. This is a figure which the average town station in this country seems unable to approach. It is stated that there is a useful domestic load in Pretoria, and while there is quite certainly also a useful domestic load in many English towns, our home variety seems quite unable to produce a load factor of anything like the order of 40 per cent. We are here concerned with a description of the new Pretoria power station, and cannot now discuss the reasons for the low average British load factor, but this instance of Pretoria is further evidence that very considerable progress is still possible in the future of the electricity-supply business in this country.

The new Pretoria station takes the place of an original direct-current station situated near the centre of the city and erected in 1891. The conditions under which this early station was erected and its equipment well illustrate the developments which have taken place both in South Africa and in electricity supply in something over thirty years. The station was equipped with five belt-driven direct-current generators, and at the time of its erection was situated 200 miles from railhead. The present electrical engineer to the Pretoria Town Council, Mr. T. C. Wolley-Dod, was one of the party which transported the early plant in ox-wagons, and it is largely due to his energy and initiative that Pretoria now possesses such a model installation. The early station, which was erected by a private company, proved a very successful enterprise, and within ten years was carrying six times the initial load. Between 1891 and 1919 the station was reconstructed three times on its original site, and when, in the latter year, further extension was necessary, the decision to build an entirely new station was come to. The electricity undertakings had been taken over by the Municipality in 1902, and when in 1919 it was decided that further important extension was necessary, Mr. G. M. Clark, M.Inst.C.E., was appointed consulting engineer to the scheme. It is due to Mr. Clark that the decision was come to to move out of the central area and to build a modern station in a position well situated from the point of view of coal and water supplies and with ample space for future extensions.

The new station, an external view of which is given in Fig. 1 on Plate XX, is situated about three miles from the centre of the city. A railway siding allows of coal being delivered at the station, while ample condensing water is furnished by a cooling pond 35 acres in extent, which has been formed by building a dam across a natural depression in the land. The dam, which can be seen in the foreground of Fig. 1, is of earth construction, faced with concrete slabs to prevent erosion. The reservoir formed, which is fed by streams arising in the hills which can be seen in the background on the right of Fig. 1, has a capacity of 100 million gallons. The circulating water is taken through a concrete conduit under the basement of the power station engine-room, and is discharged through a concrete flume to the far end of the reservoir. The screening arrangements for the intake side of the water conduit are placed at such a level that the supply can still be used if the water level has sunk by 13 ft. after a prolonged dry season. The power house itself, which was designed by Mr. Clark without the assistance of any architect, is, as will be seen, of striking appearance. It is of monolith-concrete construction, with red-brick panels. The foundations are taken down to the rocky shale which underlies the site. In view of the temperature reached during a part of the year, the walls are hollow, with a 1½-in. space between two 4½-in. brick panels. The roof is of double corrugated iron sheet carried on the two sides of the purlins, thus also giving a hollow construction with an air space. The Pretoria Portland cement used was of local manufacture, while the steel employed for reinforcement was also of South African manufacture, coming from Vereeniging.

The station consists of five bays, one each of which cover the boiler house, pump-room and engine-room, the remaining two accommodating the switchgear. The general lay-out is such that the boiler and engine-room are on such a level that ash collection is possible practically at ground level, which much facilitates an operation always troublesome and frequently demanding expensive plant. The floor level decided on was determined by the minimum water level to be anticipated in the cooling pond. Considerable attention has been paid to the natural lighting of the building, and ample windows are provided on all sides. The excellent effect of this will be evident from the view of the boiler-room, engine-room and basement, given in Figs. 2 to 4, on Plate XX. The view in the basement in particular, having been taken without artificial light, is very striking.

The boiler-house is equipped with six Babcock & Wilcox marine-type water-tube boilers, each with a normal capacity of 20,000 lb. of steam per hour. They can, however, supply up to 30,000 lb. The pressure is 350 lb. per square inch and the final temperature 600 deg. F., figures which place the station well in line with the most modern practice. The boilers are fitted with motor-driven chain-grate stokers, and have steel-tube economisers with a main flue above. The chimney stacks are 7 ft. 6 in. in diameter, and are fitted with induced-draught fans. The motor of one of these fans can be seen below the right-hand window in the background of Fig. 2. Coal is brought to the station in wagons of 50 short tons capacity, and is discharged into a hopper whence a belt-conveyor, running in a tunnel, carries it to the power house. A bucket-elevator then raises it to a second conveyor which discharges into overhead steel bunkers. These supply the boilers through chutes, the top of each chute being fitted with a coal valve which discharges 700 lb. at each filling. The overhead bunkers have a capacity of 100 tons. Provision is made for storing up to 3,000 tons of coal on the site. The ashes are discharged into trolleys which are wheeled away by native labour.

The main power equipment of the station consists of three 3,500 kv.-a. turbo-generators the steam ends being made by the Fraser and Chalmer's Engineering Works of Erith, and the alternators by the General Electric Co., Limited, of Witton, Birmingham. They can be seen in the general view of the engine-room, given in Fig. 3. The turbines are of the impulse type and are of special interest in view of the steam conditions of 350 lb. per square inch and 600 deg. F. The vacuum is 95 per cent. It should be noted that the station stands at 4,360 ft. above sea level, and that the normal barometer is 25·5 in. Each turbine is fitted with three throttle valves, all of which are automatically operated by the governor through oil relays. The first throttle valve, which enables the machine to carry three-quarter load, is contained in a separate steam chest. The other two, which carry full load and 1¼ load respectively, are arranged together in a second steam chest. These steam chests are bolted to the bottom half of the high-pressure casings. The double arrangement has been used with a view to obtaining reliable steel castings of simple design. The steam leaving the steam chests enters the steam belt formed in the high-pressure casing, the nozzles for the first expansion being fixed to the steam belt in the bottom half only, no live steam being admitted to the top half of the high-pressure casing. The steam belt of the bottom half casing is closed at the horizontal joint. This arrangement has the advantage that none of the joints which have periodically to be broken for examining the interior of the turbine are subject to live steam pressure. The steam pressure after the first expansion is no greater than the turbines of similar capacity working with moderate live steam pressures. The heat drop in the first expansion is considerable, and a velocity-compounded stage has been introduced to secure the best possible blade efficiency. In addition, there are eight single impulse stages. In details, the turbines follow Fraser and Chalmers standard practice.

The condensers, which each have a cooling surface of 6,000 sq. ft., were built by Messrs. Worthington-Simpson, Limited. The circulating pumps and other auxiliaries are electrically-driven by three-phase motors which operate on a 500-volt circuit. The motors are of "Witton" type, supplied by the General Electric Company, and are provided with auto-transformer starters and oil-break circuit-breakers. A view of some of the auxiliaries in the basement is given in Fig. 4. As before mentioned, there is a pump-room bay between the boiler-house and engine-room. A view of this is given in Fig. 5 on Plate XXI. It contains the turbo-feed pumps, feed-water heaters, and measuring tanks. The feed pumps, which were built by Messrs. G. and J. Weir, each have a capacity of 7,000 gallons per hour against full boiler pressure; they run at 6,000 r.p.m. The exhaust from the pump turbines is taken to the feed-water heater, and the feed water is delivered to drums, from which it is distributed to either or both duplicate-feed ranges. A Weir evaporator for supplying make-up feed is also situated in the pump room; it can be seen in the foreground of Fig. 5. The room also contains an air compressor, supplying a service which is carried to all parts of the station and is used for soot-blowing, &c. The piping system throughout the station is painted in a conspicuous way, so that any service may easily be followed through. Main steam pipes are white, exhaust pipes yellow, feed ranges chocolate-red, fire services vermilion, &c. The main steam range flanges are riveted with a mild-steel ring inserted to form a caulking piece, except at the junction of pipes to valves, &c., where bolted joints with serrated rings are used.

The alternators are of the General Electric Company's standard design rated at 3,500 kv.-a., and delivering three-phase, 50-cycle current at 6,600 volts. The speed is 3,000 r.p.m. The machines were designed for a power factor of 0·8, but, owing to the considerable converter load on the mains, the power factor is nearly unity. The main high-tension switchboard, which consists of a stoneware structure, contains three cubicles for the control of the alternators, two works cubicles, one 'bus-bar-coupler cubicle, and three cubicles each controlling one 2,200-kv.-a. feeder. The main gear is situated at engine-room level, while the 'bus-bar chambers are placed on the floor above and behind the control board on the gallery, which can

# THE LENTZ VARIABLE HYDRAULIC TRANSMISSION GEAR.

CONSTRUCTED BY MESSRS. HAWTHORN, LESLIE AND CO., LIMITED, ENGINEERS, NEWCASTLE-ON-TYNE.

*Fig. 1.*

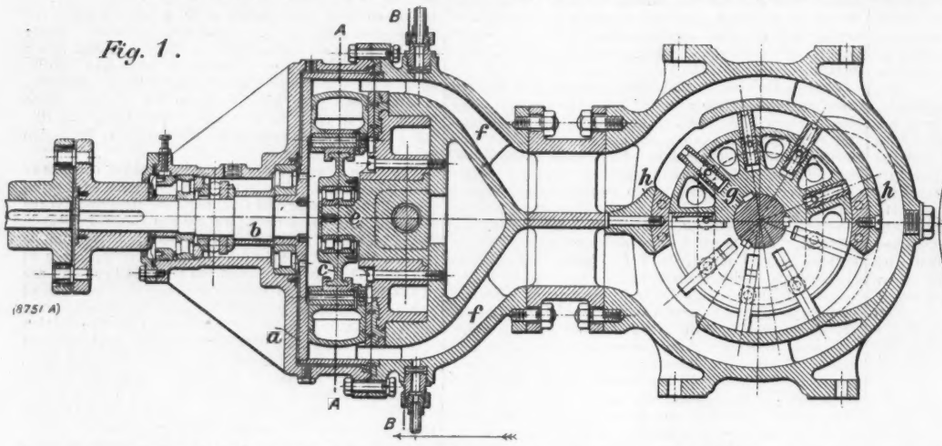



*Fig. 2. SECTION A.A.*

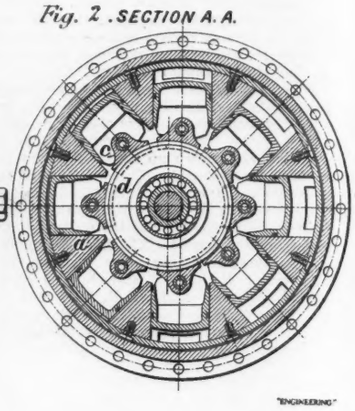
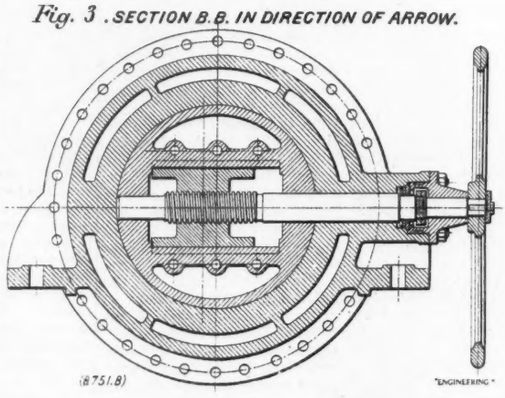



*Fig. 3. SECTION B.B. IN DIRECTION OF ARROW.*




be seen in the general view of the engine-room given in Fig. 3. Duplicate links are provided on each side of the oil circuit-breakers, so that any cubicle, or any 'bus-bar, may be isolated for inspection or cleaning. A view of one of the circuit-breaker cubicles is given in Fig. 6 on Plate XXI, and a general view of the cubicles from the circuit-breaker side in Fig. 9 on the same plate. The circuit-breakers, as will be seen, have each phase in a separate oil tank. They have a breaking capacity of 125,000 kv.-a. The control-board, which, as already mentioned, is placed in the engine-room gallery, consists of flat-back slate panels. It is illustrated in Fig. 7 on Plate XXI. The equipment consists of the usual instruments, synchronising gear, reverse, overload and protective relays, and the handles controlling the switches for energising the operating solenoids of the circuit-breakers. The whole of this switchgear, as well as the works board to which we refer below, was supplied by the General Electric Company, Limited.

The works board, which is illustrated in Fig. 8 on Plate XXI, is situated below the gallery on the engine-room floor level. It is a steel-cubicle structure, and contains lighting and works panels and a panel for a petrol-engine charging set, which forms, we think, something of a novelty as part of a power-station equipment. This set, which at times should prove a very useful stand-by, consists of a petrol engine coupled to a double-ended alternator and direct-current generator. The set can be used for battery charging or to supply alternating-current power, and in the event of a shut-down provides power to the auxiliary motors for starting-up again.

As already stated, the load factor of the station is 40 per cent; its maximum load is, at present, something over 4,000 kw. The main supply is to the converter station at Schoeman-street, which has been adapted from the original generating station. This station, which contains five 750-kw. motor converters, is also equipped with switchgear supplied by the General Electric Company. There are also seven other smaller sub-stations, the most distant of which is eight miles from the generating station. The coal burnt at the station has a pit-head price of 1*s.* 6*d.* per ton, and is said to be unsaleable for other purposes; it consists of 50 per cent. peas and 50 per cent. fine slack, and has a calorific value of 12,000 B.Th.U. per lb. The consumption is 2 lb. of coal per unit generated. The total cost of the station was 250,000*l.*, including buildings, but exclusive of the dam and the land; this latter was municipal property before the station was contemplated. The station thus works out at 25*l.* per kilowatt, of which 10 per cent. was absorbed in transport costs. A further 75,000*l.* was spent on the converter station and on mains. The figures were 1921 prices, when costs were rather high. In view of the excellent load factor, it will be of interest to mention, in conclusion, that the consumption of electricity in Pretoria per head of white population works out at 300 units per annum.

## THE LENTZ VARIABLE HYDRAULIC TRANSMISSION GEAR.

We illustrate in Figs. 1 to 7 above, and on page 354, an example of the Lentz hydraulic gear manufactured by Messrs. Hawthorn, Leslie and Co., Limited, of Newcastle-on-Tyne. This represents the first infinitely variable Lentz patent hydraulic transmission for locomotives built in this country, and it will be recalled by our readers that an example of this gear was exhibited on Messrs. Hawthorn, Leslie's stand at the British Empire Exhibition last year. The gear is finding application for the same purpose on the Continent, many internal-combustion-engine locomotives employing this gear having been built on the Continent. These engines range from the smallest sizes up to 1,200 h.p., and have given full satisfaction in a wide variety of duties.

The gear is of the type utilising oil as the medium of transmission, and it will be evident that it is likely to have extended application entirely apart from locomotive work. It permits of very large direct reductions, and may be arranged either as a multi-speed gear, giving any required number of definite reduction ratios as required, or, alternatively, to give an infinitely variable speed-range.

Turning now to the illustrations, it will be seen that the pump and rotor are self-contained within one casing, the variation in the speed ratio being obtained by turning the handwheel shown in Fig. 3. As illustrated, the driving and final transmission shafts are shown at right angles, this being the most convenient arrangement for locomotive practice, but one of the advantages of the gear is that the two shafts can be arranged at any desired relative angle without difficulty. The general working of the gear will be clear from the illustrations. From Fig. 1 it will be seen that the cylinder casing *a* is fixed to the driving shaft *b* the latter being coupled to the engine. The cylinder casing is bored radially for the reception of eight pistons, which, as seen in Fig. 2, are attached to a series of bearing blocks *c*, fitted with lugs which engage with a centre cam *d*. The latter is mounted on a roller bearing which revolves on the projecting pin of an eccentric block *e*. As will be seen from Fig. 3, this block slides in a guide, and its position is regulated by a screw thread formed on a control spindle, by means of which the position of the block can be varied at will. The cylinder spaces above the pistons are in communication with ports *f*, which can be seen clearly in the longitudinal section, Fig. 1. It will be evident that when the block carrying the piston group is in the central position, rotation of the driving shaft will drive the group without any relative movement between the pistons and the cylinder casing. If the block is set eccentrically, as shown in Fig. 2, the motion of the pistons will be similar to that occurring in a radial engine, and if one piston is followed round it will be seen that the space above it increases in a half-revolution from zero to a maximum, and again decreases to zero in the second half-revolution. Evidently, therefore, if oil enters during the first half, it will be forced out again during the second half-revolution, and the amount of oil circulated will depend on the eccentricity of the centre block. As will be seen from Figs. 1, 4 and 5, grooves are provided to secure an oil-tight face between the cylinder block and the casing on the pressure side, oil-tightness being secured throughout the remainder of the gear by the accurate fit of the various parts. When driven out of the cylinders in the manner described, the oil passes along one or other of the ports *f* to the rotor casing, and the oil exhausted from the latter returns by the alternative port to fill up the cylinders in which the pistons are on the intake stroke. The direction of oil flow, and, therefore, of the rotation of the final transmission shaft, is dependent upon the position of the block in the guide, a reversal of rotation taking place when the block is screwed through the central position. Turning now to the action of the rotor, it will be seen in Fig. 1 that the port from the pump divides into two passages, part of the oil entering the rotor chamber through the upper inlet and the rest through another passage below. There are corresponding vent passages in the casing through which the oil escapes and passes back to the suction side of the pump, as explained above. The rotor is thus double acting, the object of this arrangement being to balance the torque. The rotor *g* which is mounted on the final driving shaft of the gear, is accurately machined to make an oil-tight contact with the blocks *h*. These blocks are stationary, and means must therefore be provided for the withdrawal of the rotor vanes to allow them to pass these fixed points. This is done by the provision of a roller mounted on a pin fixed in each end of the vane, the rollers running in cam paths, one of which is shown dotted in Fig. 1.

Figs. 4 to 7 show various views of the actual gear. In Fig. 4 the casing is split across the bolt line lying between the sections A A and B B in Fig. 1, and the oil ports and block *e* are thus rendered visible, the pin on the latter carrying the ball races on which is mounted the piston group. Fig. 5 shows the other half of the casing with the pistons in position, and the other two figures show the rotor in position in the casing and separately. The rollers mounted on the ends of the vanes can be clearly seen in Figs. 4, 6 and 7, and the latter figure also clearly shows the oil ways in the edge of the vanes, which serve to seal the latter.

The efficiency of the gear lies between 80 and 85 per cent, 82·6 per cent. having been recorded during an official test of a similar gear carried out by the Austrian Federal Railways. In a test carried out by Mr. H. N. Gresley, C.B.E., the Chief Mechanical Engineer of the London and North Eastern Railway, on an engine of Austrian manufacture fitted with the Lentz gear, the rise in temperature of the oil in the gear over a run from Tottenham to Cambridge was found to amount to only 36 deg. F., and troubles arising from temperature variations are therefore unlikely to arise.

# AXLES FOR 14-H.P. MOTOR-CAR CHASSIS.

CONSTRUCTED BY GWYNNES ENGINEERING COMPANY, LIMITED, LONDON.

*Fig. 11.*

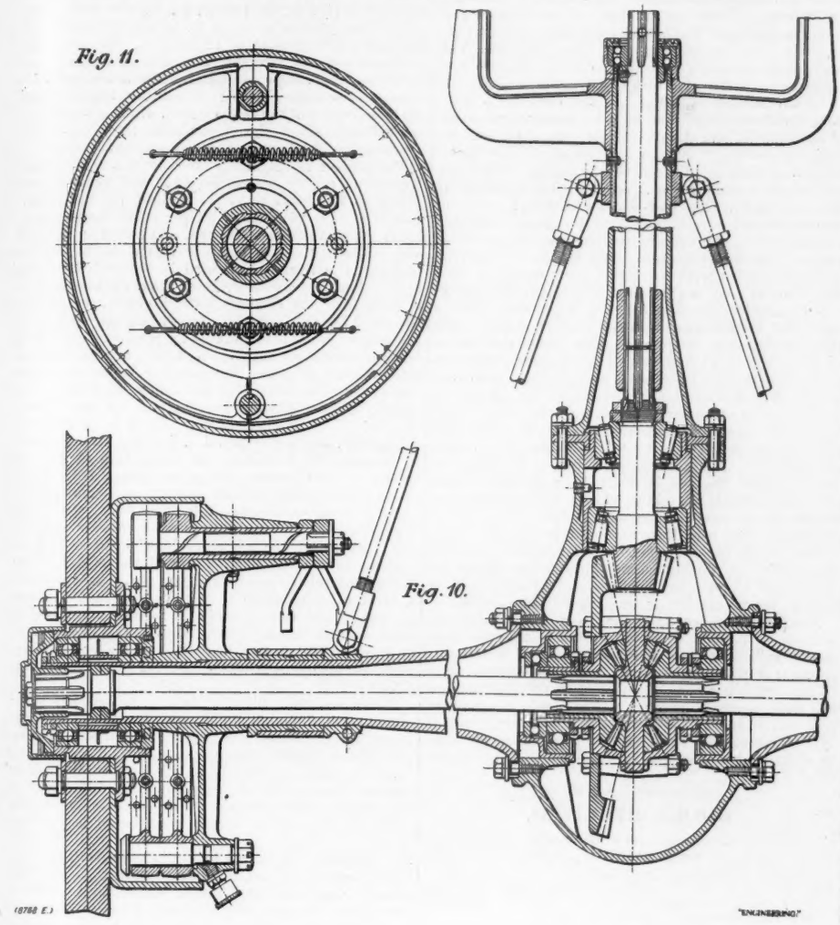


*Fig. 10.*





*Fig. 12.*

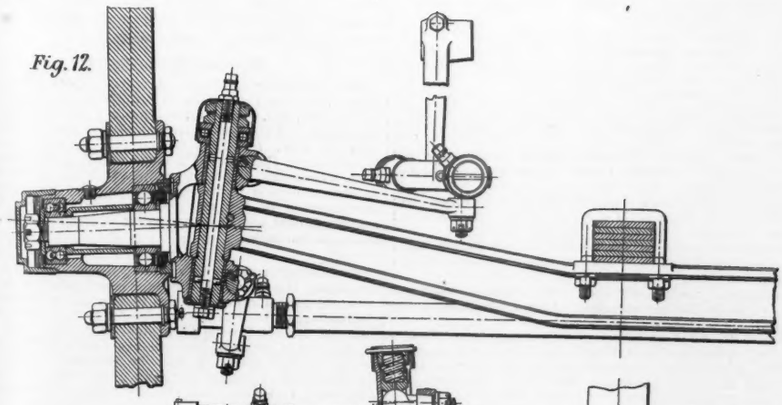


*Fig. 13.*





The sole agents for the gear in the United Kingdom and the Colonies are Messrs. W. Dederich, Limited of Dean Stanley-street, Westminster.

## 14-H.P. GWYNNE MOTOR-CAR CHASSIS.

IT is interesting to compare the 14-h.p. Gwynne car, made by Gwynne's Engineering Company, Limited, of Hammersmith, which we illustrate in Figs. 1 to 13 on this page and on Plates XXII and XXIII, with the 8-h.p. model with which we dealt in our issue of October 24 last. The general lay-out of the two cars is very similar, the differences which are at once apparent being that on the larger car a cooling fan is employed, the rear springing is of the cantilever type, the gear-box is an entirely separate unit, and the front end of the torque tube is forked and anchored independently of the gear-box. The minor differences are numerous and will be clear on comparing the detail descriptions of the two cars.

The 14-h.p. engine, illustrated in Fig. 4 on Plate XXIII, is of 75 mm. bore by 110 mm. stroke, and is therefore of approximately 2-litre capacity. It reaches its maximum power of 32 h.p. at 2,300 r.p.m. and is therefore of a lower-speed type than the smaller car engine. The compression ratio is 4·75 : 1, which is slightly higher than that of the smaller engine. The crank-connecting-rod ratio is 4·18 against 3·76. The general arrangement of the two engines is very similar, both being of the overhead-valve type with rocker arms operated by long tappet rods from the camshaft inside the crank casing. The larger engine has mushroom valves with recessed heads. As in the smaller engine, the pistons in the 14 h.p. size are of aluminium alloy, with carbon-steel connecting rods, the valves being of 3 per cent. nickel steel. An interesting feature of the pistons in the larger engine is the provision made against piston slap. Two semi-circular slots are made in the sides of the piston and the two wings formed in this way on the piston are pressed out slightly, serving to take up the piston slack without materially increasing the friction. The connecting rods run loose on the gudgeon pins which are held in the piston, thus reversing the practice adopted on the 8-h.p. model. In both cases the magneto is a C.A.V. and the carburettor an S.U. model. The only other differences of interest are that in the 14-h.p. engine the timing is by silent chain and the induction pipe is cast integrally with the cylinder block instead of being a separate casting, and that the lubricating pump is situated in the sump instead of at the end of the camshaft. The larger engine has a three-bearing crankshaft and camshaft in common with the smaller.

Turning now to the transmission system, it should be explained that the clutch on the 14 h.p. car is of the fabric-lined single-plate type. This is coupled by means of a shaft fitted with two universal joints of the flexible-disc type to the four-speed gear-box, which, as already explained, and as can be seen in Fig. 3, is separately mounted on this car, instead of forming a unit with the rear axle. Details of the gear-box are given in Figs. 5 to 9. On account of the lower speed of the engine, the top gear ratio is somewhat higher than in the small car, being 4·66 to 1 instead of 4·83 to 1. The remaining ratios are 7·5, 12·3 and 18·8 to 1, the reverse being 14·1 to 1.

Immediately behind the gear-box, as shown in Figs. 5 and 6, is another universal joint of the flexible disc type, which is mounted on the end of the cardan shaft. The torque tube fork is housed in two brackets formed on arms extending from the gear-box casing, heavy rubber buffers being fitted over the fork pins which prevent any jarring from taking place at this point. It is probable that these buffers will also act, to some extent, as an anti-rolling device. As in the case of the smaller car, provision is made to relieve the rear springs of all torsional couples, although the method adopted is somewhat different in the two cases. The rear axle is shown in Fig. 10, from which it will be seen that it is of the full floating type. The method of construction is somewhat similar in the two axles, although, in the larger, the same use has not been made of steel stampings. The ingenious arrangement for adjusting the depth of the pinion in mesh, to which we referred in describing the smaller car, is used also in this model. Four differential pinions are used instead of two as are employed in the 8-h.p. model. The car is fitted with side-by-side hand and foot brakes on the rear wheels, a separate view of the brake shoe assembly being shown in Fig. 11. Final transmission is by spiral bevel. Details of the front axle are given in Figs. 12 and 13, and do not call for special comment.

In making a comparison of the two cars, it must be borne in mind that the 8 h.p. has an exceptionally small engine and that, on this account, the weight of the various units is a matter of primary importance. For this reason some of the features which distinguish the larger car have been sacrificed in the smaller.

# LETTERS TO THE EDITOR.

## TESTS OF WATER-LINED FURNACE BOILERS.

TO THE EDITOR OF ENGINEERING.

SIR,—In your very comprehensive article on "Water-lined Furnace Walls for Power Station Boilers," in your issue of January 16, page 71 *ante*, we were particularly interested in the recorded results of tests on boiler No. 51 at the Hell Gate station of the United Electric Light and Power Company.

Although we are not responsible for the information given in the article, it would seem that the record of tests would not be complete without giving the results obtained on this same boiler on March 18–19, in which a considerably higher efficiency was obtained. You will note that, although the temperature of the water entering the economiser is lower than in the tests published, it still is within the range of temperatures given in the record of tests on large boilers which have recently been published.

It also might be of interest to note that very satisfactory combustion results are being obtained in the boilers of the Sherman Creek station of this company where the furnaces are fed with powdered coal, and that there is no indication whatever of any unfavourable effect on combustion by the water-tube walls. The test referred to is as follows :—

| | |
|---|---|
| Date of test | March 18–19, 1924 |
| Duration of tests, hours | 28 |
| *Pressures and draughts :* | |
| Superheater, lb. per sq. in. | 263 |
| Drum, lb. per sq. in. | 266 |
| Draught below economiser, in. | — 0·5 |
| Draught over fire, in. | 0·0 |
| *Temperatures :* | |
| Steam, deg. F. | 565·3 |
| Gas leaving boiler and entering economiser, deg. F. | 485 |
| Gas leaving economiser, deg. F. | 193 |
| Feed water entering economiser, deg. F. | 128·2 |
| Feed water leaving economiser entering boiler, deg. F. | 233·1 |
| Quality of steam per cent. | 98·89 |
| Superheat, deg. F. | 155·0 |
| *Fuel Analysis :* | |
| Moisture in coal as fired, per cent. | 3·80 |
| Ash in coal as fired, per cent. | 7·16 |
| B.Th.U. per pound coal as fired | 14,010 |
| B.Th.U. per pound dry coal | 14,563 |
| *Quantities :* | |
| Coal per hour as fired, lb. | 8,133 |
| Dry coal per hour, lb. | 7,824 |
| Equivalent water evaporated per hour, lb. | 99,354 |
| Do. per pound coal as fired, lb. | 12·22 |
| Do. per pound dry coal, lb. | 12·70 |
| *Rating and Efficiencies :* | |
| Evaporated from and at 212 deg. lb./hr. | 99,354 |
| Do. per square foot of heating surface, lb./hr. | 6·24 |
| Combined efficiency of boiler, furnace, and superheater, per cent. | 84·6 |
| Combined efficiency of boiler, furnace, superheater and economiser, per cent. | 92·7 |
| *Gas analysis* (last pass of boiler) | |
| $CO_2$ per cent. | 13·04 |
| $O_2$ per cent. | 6·25 |
| CO per cent. | 0·04 |

HEAT BALANCE.

| | B.T.U. | Per cent. |
|---|---|---|
| Heat per pound of coal | 14,563 | 100·0 |
| ,, absorbed by water and steam in boiler and superheater | 12,322·1 | 84·6 |
| ,, absorbed by water in economiser | 11,832·0 | 8·1 |
| ,, loss due to moisture in coal | 43·7 | 0·3 |
| ,, ,, water from combustion of hydrogen | 446·7 | 3·1 |
| ,, ,, moisture in air | 2·5 | 0·0 |
| ,, ,, dry chimney gases | 460·4 | 3·2 |
| ,, ,, incomplete combustion of carbon | 20·7 | 0·1 |
| ,, ,, unconsumed combustible in refuse | 52·6 | 0·4 |
| ,, ,, unconsumed hydrogen and hydrocarbons radiation and unaccounted for | 31·1 | 0·2 |
| | | 100·0 |

Yours very truly,
H. W. LEITCH,
General Superintendent of Power Plants,
The United Electric Light and Power Company.
130, East 15th-street, New York,
February 4, 1925.

## HEAVY CASTINGS.

TO THE EDITOR OF ENGINEERING.

SIR,—Referring to the account in your issue of March 6 of the casting of a 95-ton anvil block, it may be interesting to note that in 1866 the Bolton Steel and Iron Company cast a 205-ton anvil block for their own works; 220 tons of metal were melted, of which 8 tons consisted of Bessemer steel scrap. Two of Ireland's cupolas were used, each melting about 12 tons per hour. The coke consumption per ton was only 1 cwt. 1 qr. The blast was supplied by blowing engines at 14 in. of water pressure.

Yours faithfully,
W. SISSON.

Gloucester. March 17, 1925.

# WOLSELEY MOTOR-REPAIR DEPOT.

MESSRS. WOLSELEY MOTORS, LIMITED, have just completed a considerable extension to their service and repair depot in Manor-street, Chelsea, and the works as a whole were formally opened on Wednesday, the 11th inst. They are divided into two blocks, and as now constituted undoubtedly compare very favourably with any similar depot in Great Britain. The west block is mainly devoted to minor repairs and adjustments under the firm's guarantee scheme. It covers an area of 58,000 sq. ft. and contains a large garage with two bays, one for cars entering for repair or adjustment, and the second for completed vehicles awaiting delivery. Behind this garage is the repair shop, and leading off from the latter are tyre-repair and engine-tuning rooms, an electrical department and a kit store. The east-side works, which cover an area of 42,000 sq. ft., are used for more extensive overhaul work, and contain machine, trimming, wood-working, panel-beating and painting shops, the drying rooms associated with the latter being equipped with the "Carrier" hot-air system. The total accommodation is sufficient for about 300 cars per week, and a noticeable feature was the entire absence of pits, their place being taken by ramps. The precautions taken to avoid the small irritations to customers which are so frequently associated with garage work were also noticeable. Arrangements are made by means of which every customer who enters the depot gets immediate attention, and once the car is taken over all personal property is placed in a bin and is then transferred to a numbered steel locker, in which it remains until the car is ready to leave the works. Provision is made for taking off and storing lamps and accumulators in a similar way if the car is in for overhaul. The attention to detail in this direction is also seen in the provision made for hoisting bonnets clear of the cars during engine adjustments, the danger of damage to paintwork which so frequently occurs during this process being thus entirely eliminated.

The formal reopening of the depot was followed by a lunch in honour of Major Forbes-Leith, who with two companions has just completed a remarkable journey of 8,500 miles, from Leeds to Quetta, on a 14-h.p. Wolseley car. A great part of this distance was over roadless country, and the only involuntary stop was caused by the steering gear coming in contact with a submerged rock, the resulting damage being so slight that it was possible to repair the gear on the spot.

# BOOKS RECEIVED.

*A Danger Spot in Europe and its Government by the League of Nations.* By Sir RONALD DONALD, LL.D. London: Leonard Parsons. [Price 3*s.* 6*d.* net.]

*The History of the Telephone in the United Kingdom.* By F. G. C. BALDWIN, M.I.E.E. London: Chapman and Hall, Limited. [Price 42*s.* net.]

*Gasmaschinen und Ölmaschinen.* By ALFRED KIRSCHKE. Berlin and Leipzig: Walter de Gruyter and Co. [Price 1·25 marks.]

*Motor Cycling Manual. All About Motor Cycles and the Art of Driving Them.* By the Staff of *Motor Cycling*. Sixth edition, entirely rewritten. London: Temple Press, Limited. [Price 2*s.* 6*d.* net.]

*Report on the Progress and Condition of the United States National Museum for the Year ended June* 30, 1924. Washington: Government Printing Office. [Price 65 cents.]

*The Subject Index to Periodicals*, 1921. *K. Science and Technology.* London: The Library Association. [Price 21*s.* net.]

*Tables for Reinforced Concrete Floors and Roofs.* By R. TRAVERS MORGAN, M.Eng. London: Chapman and Hall, Limited. [Price 10*s.* 6*d.* net.]

*Mechanical Design of Overhead Electrical Transmission Lines.* By EDGAR T. PAINTON, B.Sc. London: Chapman and Hall, Limited. [Price 21*s.* net.]

*Vorschriften für Eisenbauwerke. Berechnungsgrundlagen für eiserne Eisenbahnbrucken.* Berlin: Wilhelm Ernst and Sohn. [Price 3 marks.]

*A Text Book of Metallography-Chemistry and Physics of the Metals and their Alloys.* By GUSTAV TAMMANN. Translated from the third German edition. By R. S. Dean and L. G. Swenson. New York: The Chemical Catalog Company, Inc.

*Aeronautical Research Committee.* Reports and Memoranda, No. 929. *Some Experiments on a Slotted Aerofoil.* By H. B. IRVING, B.Sc., and A. S. BATSON, B.Sc. [Price 1*s.* net.] No. 937. *Measurements of Lift, Drag and Pitching on the fifth Scale Model of the Bristol Fighter with Airscrew Running.* By E. F. RELF and L. J. JONES. [Price 1*s.* net.] London: His Majesty's Stationery Office.

TENDERS.—The Department of Overseas Trade, of 35, Old Queen-street, London, S.W.1, have announced that the Anatolian Railway Administration invite tenders until April 15, 1925, for the supply and erection of six metallic storage sheds.—The Government of the Province of Buenos Aires invite tenders to be presented in La Plata not later than May 16, 1925, for waterworks in some nine towns. All inquiries regarding these tenders should be addressed to the Department of Overseas Trade.

# THE MOTOR-TUG "SPARTEOLUS."

A STEEL tug, designed by Messrs. Perman and Company, Limited, of 82, Fenchurch-street, London, and built by Messrs. Edward Hayes, of Stony Stratford, in which a Kromhout marine oil engine is fitted, was put into service on the Thames on Tuesday last. This vessel, the Sparteolus, is 54 ft. in length overall and has a moulded breadth of 12 ft. 4 in. The stem and counter-stern are straight, and the steel deck has bulwarks 15 in. high around it. The accommodation consists of a cabin between the collision bulkhead and the forward end of the engine-room, which is amidships. Immediately aft of the engine-room there is a space available for stores and then a rope room.

The propelling machinery consists of a two-cylinder Kromhout engine which develops 100 brake horse-power at 320 revolutions per minute and has a consumption of 0·48 pints of oil per brake horse-power-hour. A combined reverse gear and clutch is provided and is fitted up on a bedplate bolted to that of the engine. The thrust-block used is of the ball-bearing type. A feature of the cylinder heads of these engines is that they are entirely water-jacketed, except for the small ignition pockets. In starting up, these parts are heated for a few minutes by means of special oil burners, which are supplied with air pressure from the general system. Once the pressure is put on, these burners may be started by the simple application of a lighted taper. When once the engine has been started by the use of compressed air, stored in bottles, the oil burners are not required under any circumstances of running, the heat from the combustion of the fuel in the cylinder keeping the ignition system hot. There is no light-running device needed, and consequently there is little of complication about the ignition and fuel systems. The fuel pumps used are cam-operated and they inject the oil under high pressure into the cylinder-head. Another feature of the engine is the Kramhout roller type of gudgeon-pin. An automatic control of the engine is provided by a centrifugal governor, and consequently it is only necessary to have a single control lever. However, a second lever is provided for varying the speed whenever necessary, after the clutch is in action and the propeller is being driven.

There are two plunger pumps provided for the circulation of jacket water and to deal with bilge respectively. These are worked from an eccentric on the crankshaft. Since a starting and charging-air valve is fitted to the engine, the air bottles may be pumped up by the main engine. In consequence of this, there is no necessity for an auxiliary engine for compression purposes, but, in case the air may be lost at any time, a Reavell hand air compressor is installed. The propeller, which is 4 ft. in diameter, is of the solid four-bladed type and is made in cast-iron. For fuel storage there are three tanks, which hold a total of 560 gallons, or sufficient for running at full power for over 90 hours. This tug was built to the order of Messrs. A. H. Green and Co., Limited, of Lower Thames-street, London, and will be used by them in association with Messrs. Bowaters' paper mills.

THE INSTITUTION OF MINING ENGINEERS.—The Council of The Institution of Mining Engineers, Cleveland House, 225, City-road, London, E.C.1, have awarded the Mayor and Coulson Travelling Post Graduate Scholarship of 250*l.* for 1925-26, to Mr. Launcelot John Barraclough, Bachelor of Science (Mining), of Birmingham University. The successful candidate is required to devote a year to the special study by underground investigation of the methods practised in the actual mining of coal and in transporting it from the face to the main haulage.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.—In proposing the toast of the petroleum industry at the seventh annual dinner of the Institution of Petroleum Technologists, held in the Connaught Rooms on Tuesday last, Sir Robert Burton Chadwick, M.P., remarked that oil was one of the most important factors in world politics at the present time. It had, he thought, affected the development of humanity more even than steam and electricity had done, and the few commercial organisations controlling it were almost as powerful as governments. As a shipping man, however, he could best visualise the commercial value of oil from the economy it effected in the propulsion of ships. Sir Frederick W. Black, in responding, said that the petroleum industry was performing some essential services to mankind with high efficiency and at a relatively low cost. The industry itself seemed a little steadier than it had been in the past, the matter of over-production being well in hand. He referred also to the work of geologists, engineers and chemists, the latter particularly in connection with cracking processes. By cracking, motor spirit was obtained at the expense of fuel oil, but it provided a means of utilising our natural resources more economically. An interesting feature of the occasion was the presentation by the President, Sir Thomas H. Holland, of the first Boverton-Redwood medal to M. Paul de Chambrier for the paper he read before the Institution in February, 1921, on "Petroleum Mining by Shafts and Galleries," see ENGINEERING, vol. cxi, page 202.

## NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

*Hull Coal Traffic.*—The latest official returns show that, despite tempting offers of lower prices for export business, shipments to most of the principal buyers overseas are still markedly on the down grade. The total received at Hull last month from South Yorkshire, 354,482 tons, was 77,979 tons below that for the corresponding month last year. Exports only reached 139,032 tons, as compared with 167,929 tons for February, 1924. A big falling off in purchases was shown in the case of Germany, France, South America, and Belgium. This was slightly offset by increased sales to Holland and Sweden.

*Iron and Steel.*—The continued failure of the heavy trades to attract sufficient business to enable firms to operate profitably is beginning to undermine optimism. Towards the end of last year hope was widely entertained of a slow but steady improvement in heavy steel and engineering products, but the new year is completing its first quarter without any advance having been recorded. The general position, according to leading employers, is worse than it was in December last. Foreign competition for the limited amount of business passing, though less acute in some directions, is more marked in others, and the struggle to replenish order books becomes increasingly difficult in face of the weight of overhead charges that has to be borne. The effect is particularly noticeable in regard to basic steel and railway materials. Orders from British railway companies have assisted railway departments to carry over a very awkward period, but foreign purchases of rails and axles are lower than was the case twelve months ago. The slump in basic steel has resulted in a further restriction of output, though there is still considerable activity in acid steel production. German cold-rolled strip of inferior quality is being offered at pounds per ton below the British price. Automobile steel and mining machinery continue to represent the brighter side. Orders are badly wanted for drills and other high-speed tools, but, on the other hand, there is an increased demand for several classes of tools made from ordinary steel. Sales of farm tools appear to be in the ascendant both on home and export account. Foundries specialising in malleable iron products report an increased output. Business is still to be picked up with Russia on the cash-with-order basis in edge tools and implement parts.

*South Yorkshire Coal Trade.*—The continued weakness of the export market neutralises the effect of a minor improvement in certain sections on home account. House coal is going away better from collieries and depots. Best quality sorts are fairly firm at former rates, and though there is an abundance of cheaper grades on offer, prices remain unchanged. Cobbles and nuts are dull owing to the existence of increased stocks, with the result that Derbyshire best large nuts have declined on the average 1*s.* 9*d.* per ton during the past week. There is keen competition for new business in slacks. All grades of coke show weakness. No improvement can be recorded in steam coal. Quotations :—Best branch hand-picked, 30*s.* to 33*s.*; Barnsley best Silkstone, 26*s.* to 28*s.*; Derbyshire best brights, 26*s.* to 31*s.*; Derbyshire best house, 24*s.* to 26*s.*; Derbyshire best large nuts, 20*s.* to 24*s.*; Derbyshire best small nuts, 14*s.* to 16*s.*; Yorkshire hards, 18*s.* to 22*s.*; Derbyshire hards, 18*s.* 6*d.* to 22*s.*; rough slacks, 10*s.* to 12*s.* 6*d.*; nutty slacks, 8*s.* 6*d.* to 10*s.*; smalls, 4*s.* to 6*s.* 6*d.*

## NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

*The Cleveland Iron Trade.*—Statistically, the Cleveland pig-iron trade is in quite a healthy state, makers having small stocks, but sales are not easily arranged, and the outlook is anything but encouraging. A few more parcels have been sold to Scotland, and moderate sales to customers nearer home are reported, but the total quantities that are being disposed of for use in this country are on a disappointing scale, and inquiries on export account continue few and small. Makers declare that quotations are unremunerative, but they are still on the downward curve, customers claiming that they experience little difficulty in securing price concessions when they have definite business to offer. A fall of 6*d.* in recognised market prices has this week to be recorded, No. 1 now being 82*s.* 6*d.*; No. 3 g.m.b., 77*s.* 6*d.*; No. 4 foundry, 76*s.* 6*d.*; and No. 4 forge, 75*s.* 6*d.*

*Hematite.*—Producers of East Coast hematite are resisting downward movement, but they have very considerable unsold accumulations at their works, which they are anxious to dispose of, and which threaten to increase. Under such circumstances, their effort to maintain values is unsuccessful, and Nos. 1, 2 and 3 are now on sale at 84*s.*; whilst No. 1 is put at 84*s.* 6*d.*

*Blastfurnace Coke.*—Durham blastfurnace coke is in only very moderate demand, and is weak in price. Good medium qualities are on sale at 23*s.* 6*d.* delivered to local consumers.

*Manufactured Iron and Steel.*—The various descriptions of manufactured iron and steel are slow of sale. Producers are cutting prices keenly in their endeavour to book overseas orders, and are prepared to make some concessions on the following recognised figures for home business, which are substantially above export quotations: Common iron bars, 12*l.*; iron rivets, 14*l.* 5*s.*; packing (parallel), 8*l.*; packing (tapered), 11*l.* 10*s.*; steel billets (soft), 8*l.* 10*s.*; steel billets (medium), 9*l.*; steel billets (hard), 9*l.* 10*s.*; steel ship, bridge and tank plates, 9*l.* 5*s.*; steel angles, 9*l.*; steel joists, 9*l.*; heavy steel rails, 9*l.* to 9*l.* 10*s.*; and galvanised corrugated sheets (24-in. gauge, in bundles), 16*l.* 10*s.*

## NOTES FROM THE NORTH.

GLASGOW, Wednesday.

*Scottish Steel Trade.*—There is not the slightest sign of any improvement in the Scottish steel trade, and carrying on under present circumstances is of the greatest difficulty to managements. The demand for ship plates and sections is so extremely poor that mills are only running intermittently. Orders for almost all classes of material are very difficult to pick up, and the tonnage is, in most cases, not heavy. Forward buying is practically non-existent at present, as buyers are not inclined to take any risks with general conditions as they are. Inquiries are not satisfactory and the outlook continues dull. Continental competition is not helping matters locally as a fair tonnage of material is arriving week by week. In the black sheet trade a normal state prevails, and while the recent reduction in prices brought out a certain amount of fresh business, the volume overall was not excessive, or what was expected. The export side of the trade is quieter. The following are to-day's market quotations :—Boiler plates, 13*l.* per ton; ship plates, 9*l.* 15*s.* per ton; sections, 9*l.* 10*s.* per ton; and sheets, $\frac{1}{16}$ in. to $\frac{1}{4}$ in., 11*l.* per ton; all delivered Glasgow stations. Sheets—galvanised corrugated—for export are easier at 17*l.* per ton, f.o.b. Glasgow.

*Malleable Iron Trade.*—Conditions in the West of Scotland malleable iron trade are without change. Buying is almost at its lowest point and makers cannot see any distance ahead. The export inquiry is of the poorest description at the moment. The re-rolled steel branches are quiet, but a better feeling is noticeable. Prices are nominally unchanged with "Crown" bars quoted at 12*l.* per ton delivered Glasgow.

*Scottish Pig-Iron Trade.*—With no improvement of any kind in the demand for Scottish pig-iron, there is a probability of more furnaces being blown out in the near future. Stocks are heavy, and as prices are far from satisfactory, makers do not feel inclined to continue running their furnaces and placing the bulk into stock, which is already heavy enough. Home consumers are taking up little, and the export side is very poor. Prices are unchanged, and are as under :—Hematite, 4*l.* 11*s.* 6*d.* per ton, delivered at the steel works; foundry iron, No. 1, 4*l.* 11*s.* 6*d.* per ton, and No. 3, 4*l.* 9*s.* per ton, both on trucks at maker's yards.

## NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

*The Coal Trade.*—Exports of coal from South Wales to foreign destinations as cargo in February were the smallest in volume for any similar period during the last two years. The average price realised was also the lowest for a couple of years. The total of 1,840,800 tons was 88,056 tons less than in January and compared with 1,998,605 tons in February last year and 2,275,794 tons in February, 1923. The average price realised in the past month at 23*s.* 3*d.* per ton was 8*d.* less than that secured in January and 2*s.* 1*d.* per ton below the figure secured in February of last year. The shipments from each port were as follows :—

| From | Tons. | £ | Per Ton. *s.* | *d.* |
|---|---|---|---|---|
| Cardiff ... ... | 1,153,432 | 1,345,945 | 23 | 4 |
| Newport ... ... | 336,525 | 388,269 | 23 | 1 |
| Port Talbot ... | 143,741 | 153,008 | 21 | 3 |
| Swansea ... ... | 207,102 | 250,165 | 24 | 1 |

At Cardiff the average price realised was lowered by 2*d.* per ton compared with the January figure, at Port Talbot by 1*s.* 11*d.*, and at Swansea by 3*s.* 10*d.*, but at Newport it remained stationary. The proportion of coal shipped from South Wales in February was only 56 per cent. of that despatched from the United Kingdom compared with 59·3 per cent. in January, whereas the English ports increased their proportion from 32·6 per cent. to 35 per cent. and the Scotch ports from 8·2 per cent. to 9 per cent. The price of coal at the English ports was also 3*s.* 8*d.* per ton less than that obtained for Welsh coal and at the Scotch ports 5*s.* 2*d.* less. Shipments of anthracite coal from Swansea and Port Talbot totalled 182,712 tons in February or 29,094 tons less than in January, while the value of 235,873*l.* was also reduced by 84,056*l.* the average price being lowered by 4*s.* 5*d.* per ton to 25*s.* 9*d.* Meanwhile a little more business is being done on the coal market, and in isolated cases collieries are more comfortably situated and able to maintain quoted prices. A considerable volume of business is, however, necessary to create anything like stability, for generally the collieries are only working about four and a-half days a week and temporary stoppages are frequent. In the circumstances buyers with choice of coals can still secure concessions for early shipment. Best Admiralty large coals rule from 26*s.* to 27*s.*, with seconds from 24*s.* to 25*s.* 6*d.* and Monmouthshires from 22*s.* 6*d* to 24*s.* 6*d.*, while dry large is weak at 23*s.* 6*d.* to 25*s.* 6*d.* In some cases smalls are a little tighter owing to reduced outputs and the fact that the colliery companies, owing to frequent stoppages, are using a larger proportion of smalls under their own boilers than is usually the case. The best steam smalls range from 15*s.* to 16*s.*, the latter price being demanded when taken without large, while the lower grades rule from 11*s.* up. Exports of coal from South Wales last week totalled 511,000 tons compared with 377,000 tons in the previous week. A shortage of ready shipping is, however, causing operators much inconvenience, and daily there are from 10 to 15 loading appliances unoccupied.

## NOTICES OF MEETINGS.

THE INSTITUTION OF MECHANICAL ENGINEERS.—To-night, at 6 p.m., at Storey's Gate, S.W.1. General Meeting. Second Report of the Marine Oil-Engine Trials Committee. Friday, March 27, at 7 p.m., Informal Meeting. Discussion on "The Cutting of Heavy Steel Sections."

THE JUNIOR INSTITUTION OF ENGINEERS.—To-night, at 7.30 p.m., at 39, Victoria-street, S.W.1. Ordinary Meeting. "Modern Transport," by Mr. S. H. Hole. Friday March 27, at 7.30 p.m., Lecturette : "Irrigation Engineering in Burma," by Mr. A. P. Morris.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Saturday, March 21, at 3 p.m., at Albemarle-street, W.1. Afternoon Lecture. Sir Ernest Rutherford, "The Counting of the Atoms." (Lecture IV.) Thursday, March 26, at 5.15 p.m. "Chemical and Physical Effects of Light (Lecture I)," by Mr. T. Thorne Baker. Friday, March 27, at 9 p.m., Evening discourse, by Sir Ernest Rutherford on "Studies of Atomic Nuclei."

THE INSTITUTE OF BRITISH FOUNDRYMEN : LANCASHIRE BRANCH, JUNIOR SECTION.—Saturday, March 21, at 7 p.m., at the College of Technology, Sackville-street, Manchester. Lecture, "Plate Moulding and the Pattern-Maker," by Mr. H. Stead.

THE HULL ASSOCIATION OF ENGINEERS.—Saturday, March 21, at 7.15 p.m., at the Hull Technical College. Lecture, "Steam Turbines," by Mr. Elce.

THE INSTITUTION OF CIVIL ENGINEERS.—Tuesday, March 24, at 6 p.m., at Great George-street, S.W.1. Ordinary Meeting. Paper to be submitted for discussion, "The Large Water-Tube Boiler," by Mr. Philip Warwick Robson, M.Inst.C.E. Wednesday, March 25, at 6 p.m. Extra Meeting. Joint Meeting with the following bodies :—The Institution of Mechanical Engineers, The Institution of Electrical Engineers, The Institution of Naval Architects, The Institute of Marine Engineers, The North-East Coast Institution of Engineers and Shipbuilders, The Institution of Engineers and Shipbuilders in Scotland, &c., which are co-operating in the work of the Special Committee on Tabulating the Results of Heat-Engine Trials. The following subject will be submitted for discussion : "A Standard Code for Tabulating the Results of a Steam-Generating Plant Trial," by Mr. W. H. Patchell, M.Inst.C.E.

THE INSTITUTION OF ELECTRICAL ENGINEERS : NORTH MIDLAND CENTRE.—Tuesday, March 24, at 7 p.m., at the Hotel Metropole, King-street, Leeds, "Design of Electrical Plant, Control Gear and Connections for Protection Against Shock, Fire and Faults," by Mr. H. W. Clothier.

THE INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.—Tuesday, March 24, at 7.30 p.m., at 39, Elmbank-crescent, Glasgow. Discussion on "Internal-Combustion Turbines," by Professor W. J. Goudie, D.Sc., and "The Manufacture of Brass Condenser Tubes, with Some Notes on an Alternative Alloy," by Messrs. G. H. Whiteman and A. Spittle.

THE NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—Wednesday, March 25, at 7.15 p.m., at Bolbec Hall, Newcastle-on-Tyne. Graduates' Meeting, "The Possible Influence of Recent Research on Propeller Design," by Mr. Calderwood. Friday, March 27, at 7.30 p.m., in the Lecture Theatre, Literary and Philosophical Society, Newcastle-upon-Tyne. General Meeting, "The Conversion of the SS. 'Bingtang,'" by Eng.-Lieut. Commander L. J. Le Mesurier, R.N. (Ret.).

THE ROYAL SOCIETY OF ARTS.—Wednesday, March 25, at 8 p.m., at John-street, Adelphi, W.C.2. Ordinary Meeting, "Wall Papers," by Mr. Henry G. Dowling.

THE ROYAL AERONAUTICAL SOCIETY.—Thursday, March 26, at 5.30 p.m., at the Royal Society of Arts, John-street, Adelphi, W.C.2. Lecture : "Modern Zeppelin Airships," by Dr. Eckener.

THE INSTITUTION OF LOCOMOTIVE ENGINEERS.—Thursday, March 26, at 7 p.m., at the Engineers' Club, Coventry-street, W.1. Annual General Meeting. "Special Machine Tools for Locomotive Work," by Mr. M. Lewis.

THE INSTITUTION OF STRUCTURAL ENGINEERS.—Thursday, March 26, at 8 p.m., at Denison House, 296, Vauxhall Bridge-road, S.W. 1. "The Strength of Steel Joists Embedded in Concrete," by Mr. W. Basil Scott.

THE INSTITUTION OF CIVIL ENGINEERS : BIRMINGHAM AND DISTRICT ASSOCIATION.—Friday, March 27, at 6 p.m., at the Chamber of Commerce, New-street, Birmingham. Lecture : "The Constructional Engineering of Aircraft," by Mr. R. K. Pierson, B.Sc.

THE MIDLAND INSTITUTE OF MINING ENGINEERS.—Saturday, March 28, at 2.15 p.m., at the Danum Hotel, Doncaster. "Notes on Devices to prevent Over-winding," by Professor J. A. S. Ritson and Mr. W. L. Grassham, B.Sc.; "Mines (Working Facilities and Support) Act, Part I, 1923," by Mr. J. H. Cockburn; "Manufacture of Coke-Oven Coke," by Dr. E. W. Smith and Mr. F. S. Townend, B.Sc.

THE DREDGER "SIR THOMAS PRICE."—Built to the order of the South African Railways and Harbour Administration by Messrs. Lobnitz and Co., Limited, at Renfrew, under the supervision of Messrs. H. G. Humby and Partner, of 13, Victoria-street, London, S.W.1, the twin-screw hopper bucket dredger Sir Thomas Price, of 1,200 tons displacement, has left the River Clyde for her destination, Buffalo Harbour, East London, South Africa, after completing satisfactory trials.

# THE LENTZ VARIABLE HYDRAULIC TRANSMISSION GEAR.

CONSTRUCTED BY MESSRS. HAWTHORN, LESLIE AND CO., LIMITED, ENGINEERS, NEWCASTLE-ON-TYNE.

(*For Description, see Page* 350.)

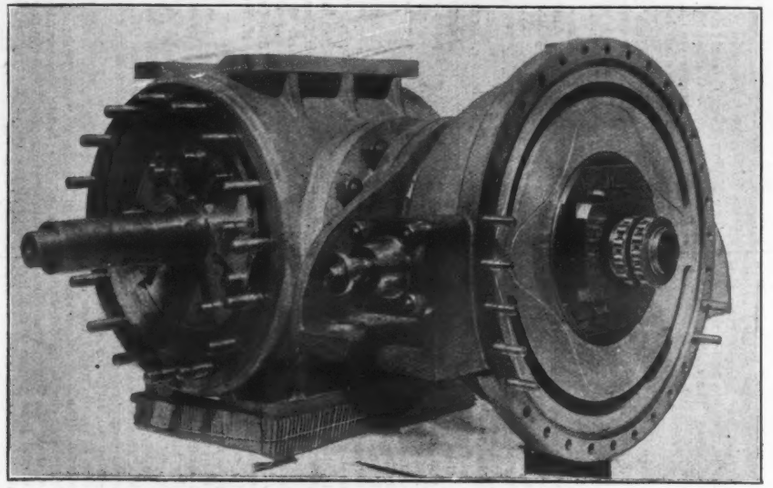


FIG. 4. GENERAL ASSEMBLY SHOWING ROTOR AND ECCENTRIC BLOCK.

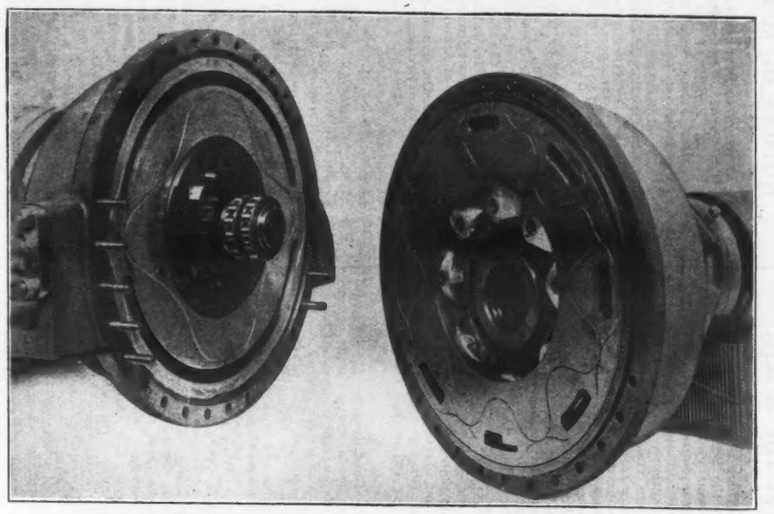


FIG. 5. CASING OPENED-UP SHOWING PISTON GROUP.

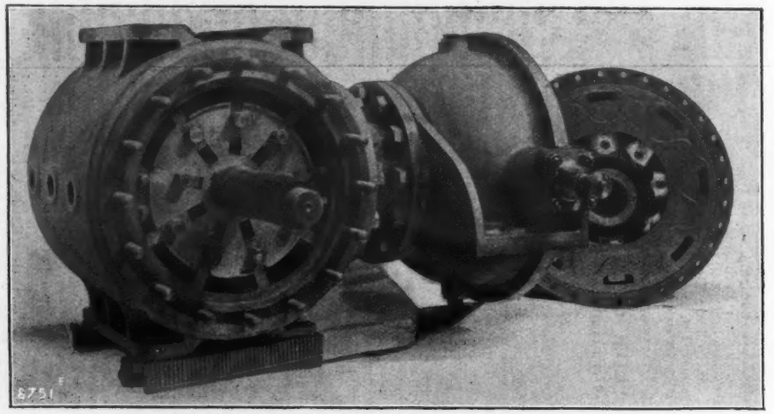


FIG. 6. END VIEW OF ROTOR CASING SHOWING ROTOR IN POSITION.

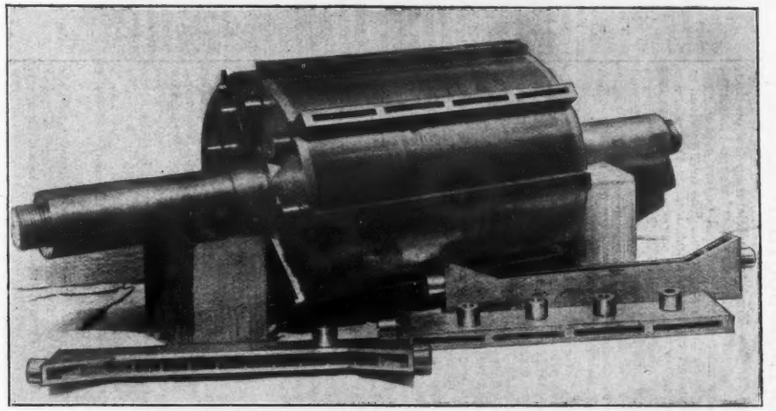


FIG. 7. ROTOR WITH VANES AND ROLLERS.

(To face page 348.)

# MUNICIPAL POWER STATION AT PRETORIA, SOUTH AFRICA.

MESSRS. G. M. CLARK AND PARTNER, CONSULTING ENGINEERS, WESTMINSTER AND JOHANNESBURG.

(*For Description, see Page* 349.)

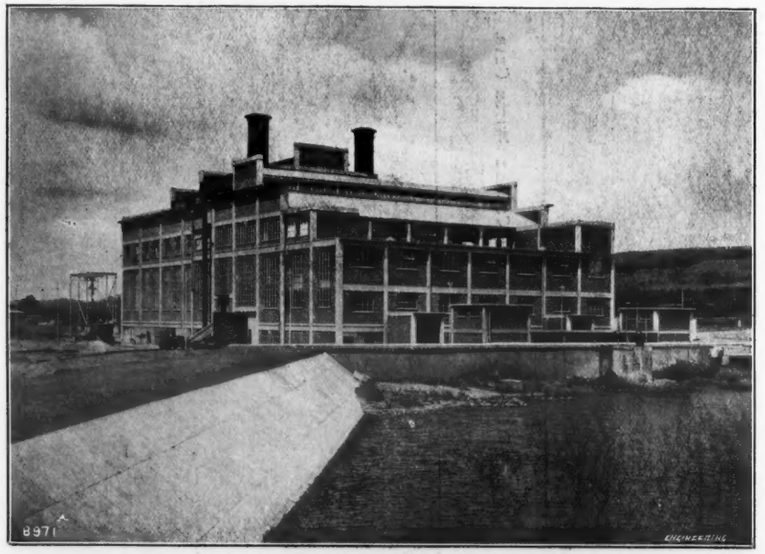


FIG. 1. VIEW OF EXTERIOR, SHOWING DAM.

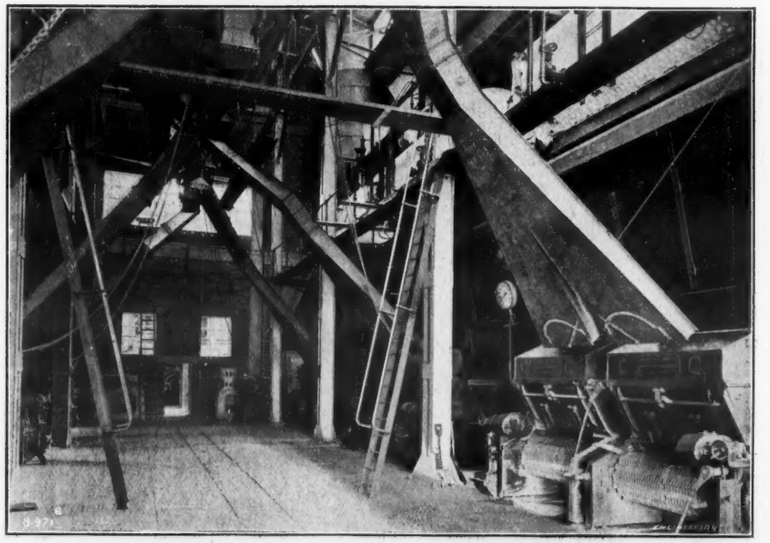


FIG. 2. THE BOILER HOUSE.

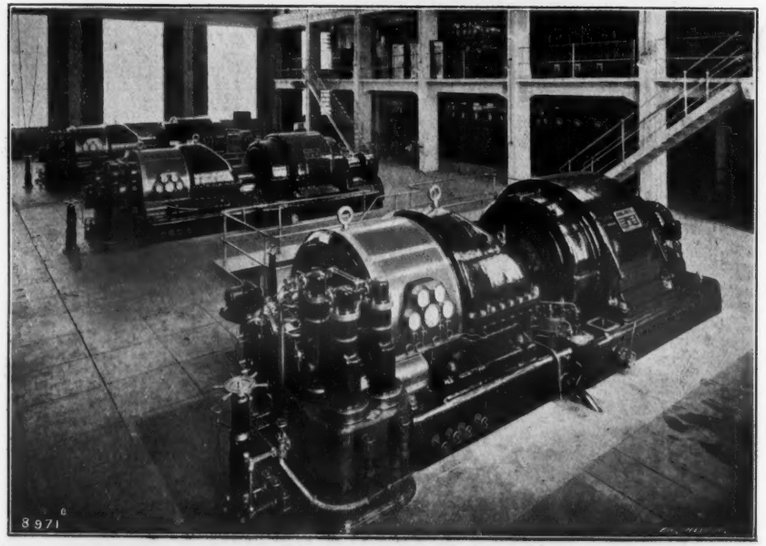


FIG. 3. THE TURBINE ROOM.

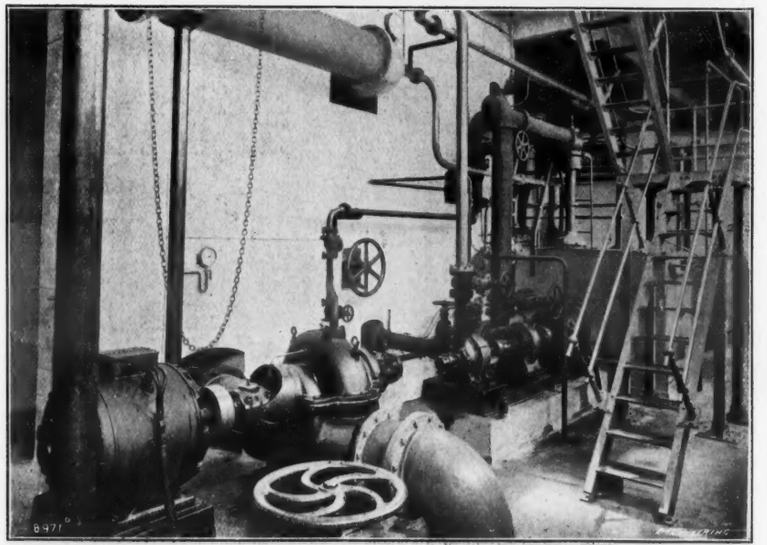


FIG. 4. AUXILIARIES IN BASEMENT.

# MUNICIPAL POWER STATION AT PRETORIA, SOUTH AFRICA.

MESSRS. G. M. CLARK AND PARTNER, CONSULTING ENGINEERS, WESTMINSTER AND JOHANNESBURG.

(*For Description, see Page* 349.)

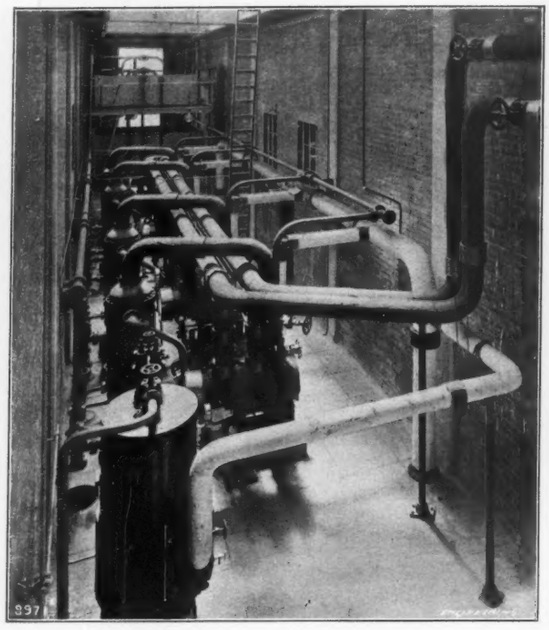


FIG. 5. THE PUMP ROOM.

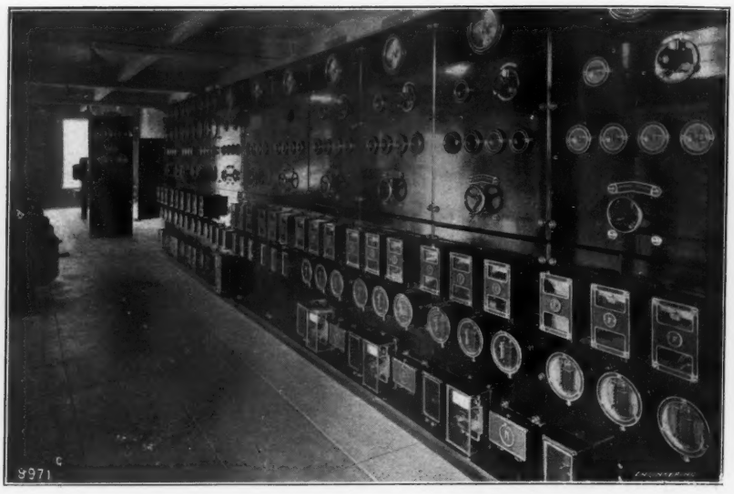


FIG. 7. 6,600-VOLT CONTROL BOARD.

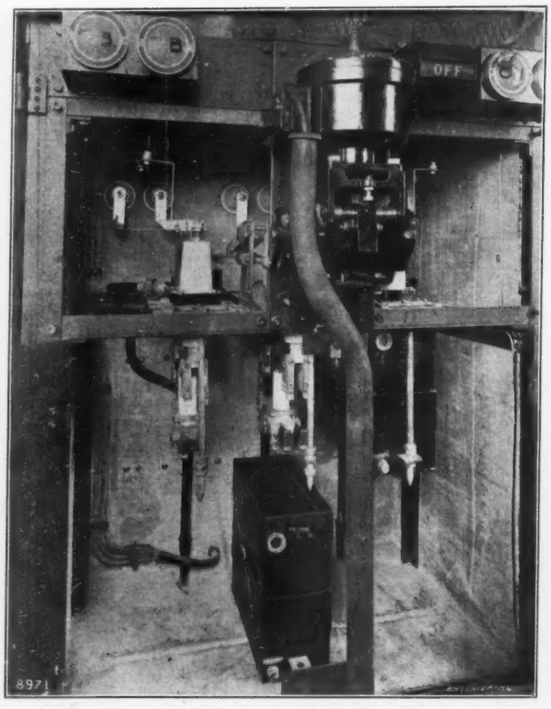



FIG. 6. 6,600-VOLT CIRCUIT BREAKER.

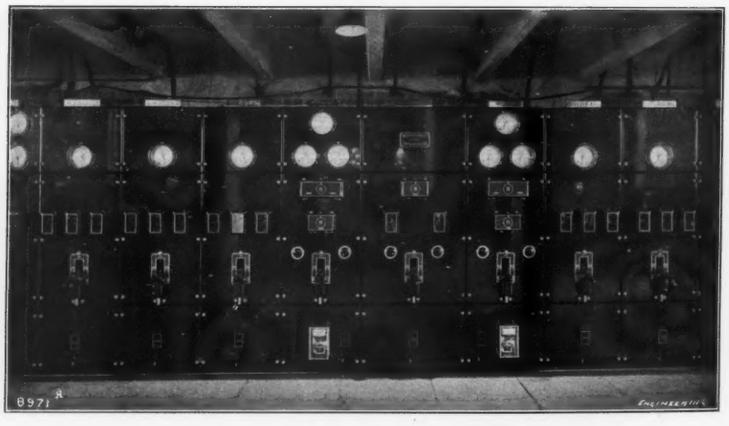


FIG. 8. 500-VOLT STEEL CUBICLE SWITCH GEAR.

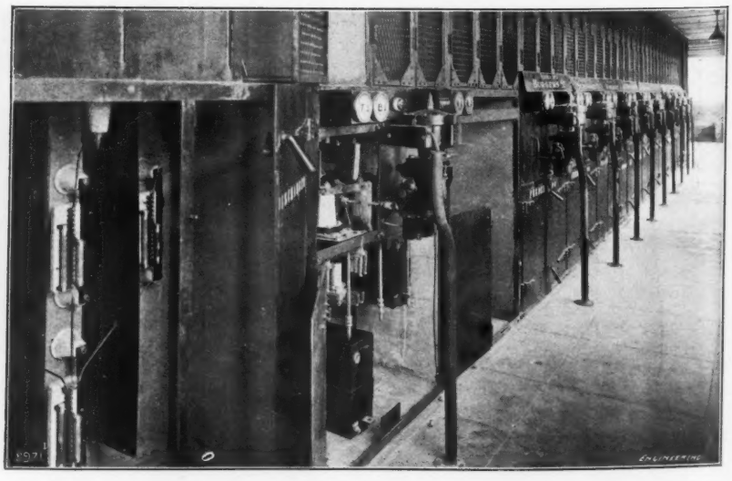


FIG. 9. 6,600-VOLT CUBICLES.

(*To face page* 349.)

# MOTOR CAR CHASSIS WITH 14-H.P. OVERHEAD VALVE ENGINE.

CONSTRUCTED BY GWYNNES ENGINEERING COMPANY, LIMITED, LONDON.

(*For Description, see Page* 351.)

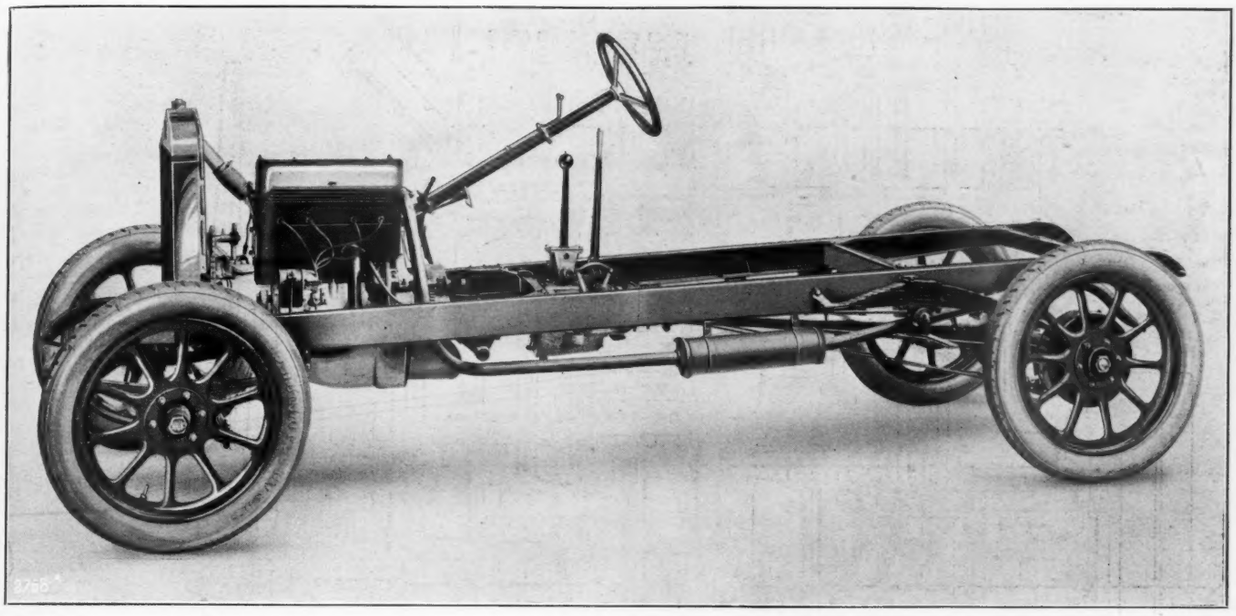


Fig. 1.

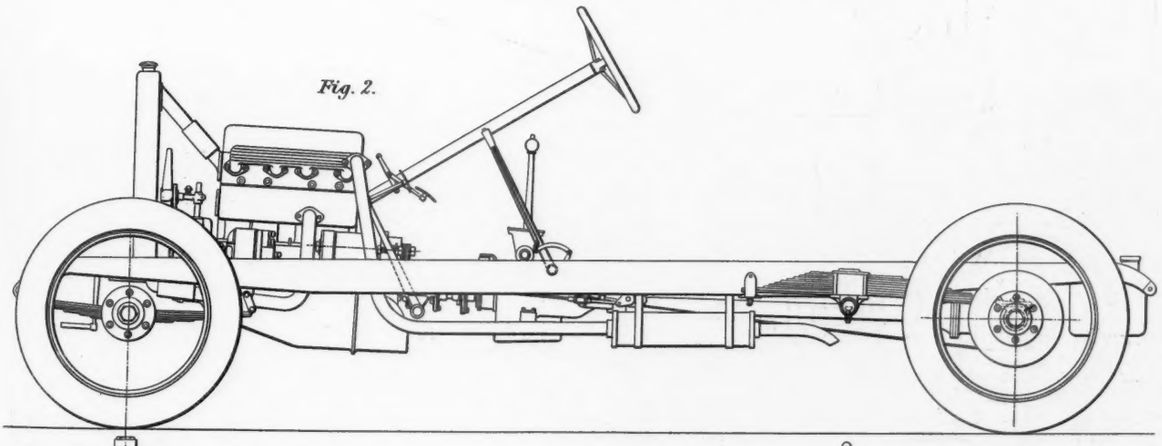


*Fig. 2.*

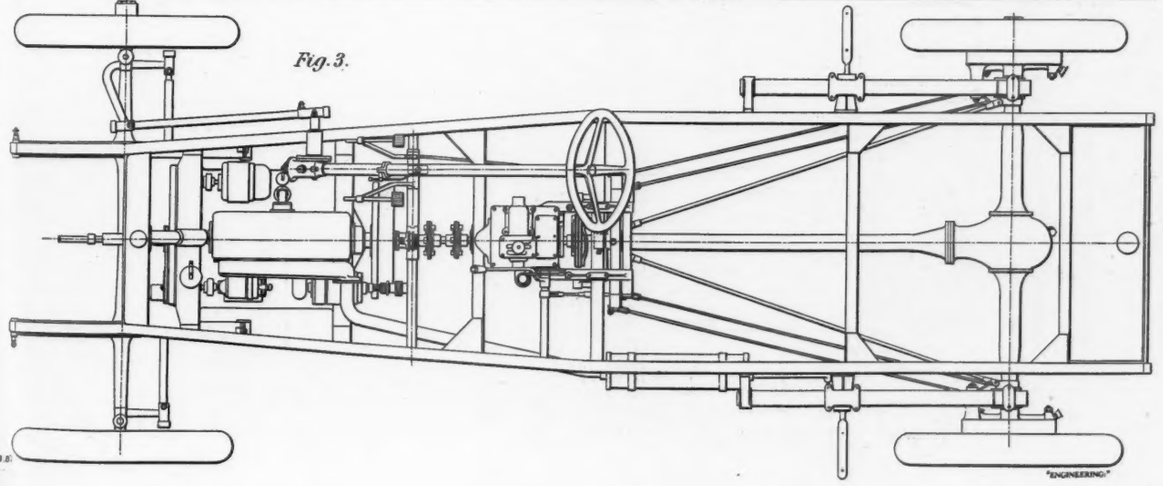


*Fig. 3.*

(*To face page* 350.)

# ENGINE AND GEAR BOX FOR 14-H.P. MOTOR CAR CHASSIS.

CONSTRUCTED BY GWYNNES ENGINEERING COMPANY, LIMITED, LONDON.

(*For Description, see Page* 351.)

*Fig. 4.*

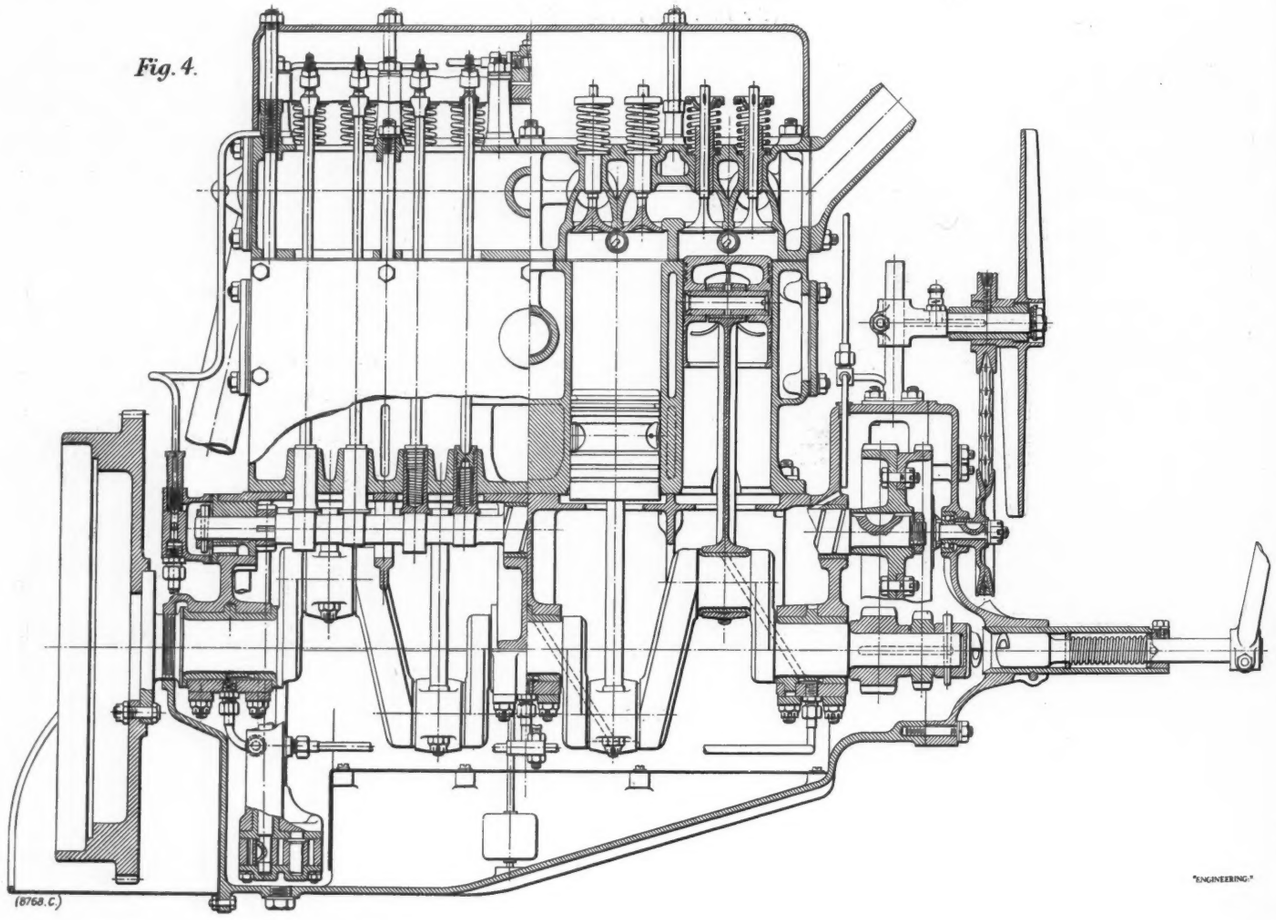



*Fig. 5.*

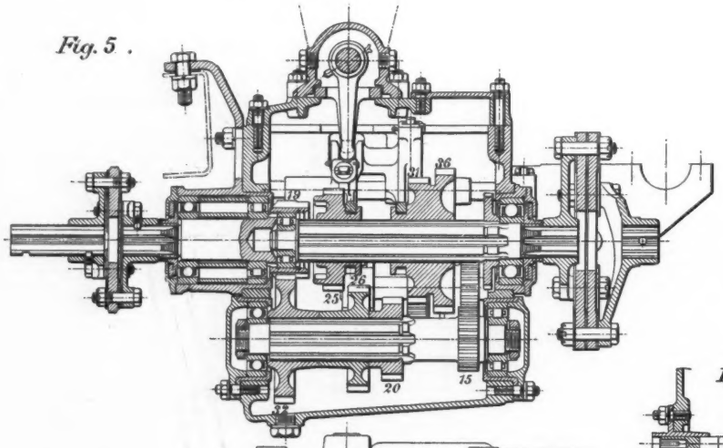



*Fig. 6.*

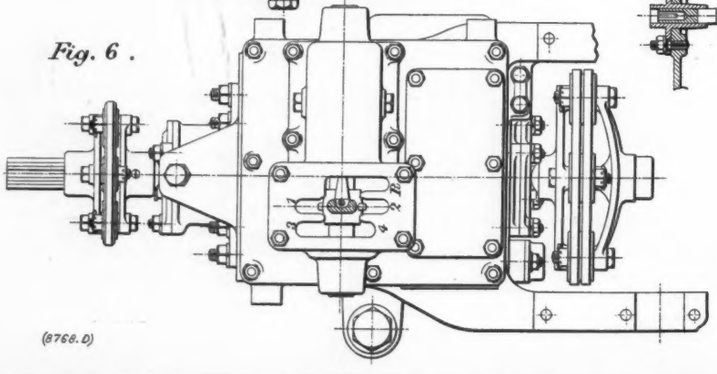



*Fig. 7.*

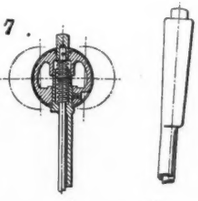


*Fig. 8.*

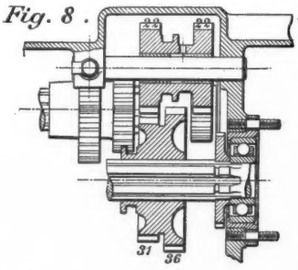
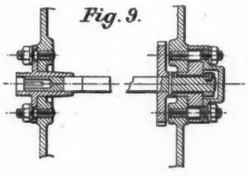
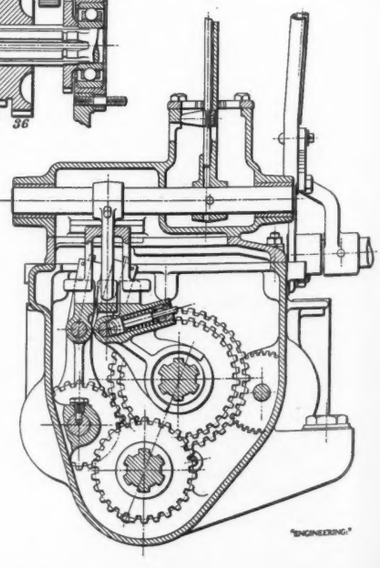



*Fig. 9.*






(*To face page* 351.)

# ENGINEERING.

**Offices for Publication and Advertisements, 35 and 36, Bedford Street, Strand. London, W.C.2.**

We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

TELEGRAPHIC ADDRESS } "ENGINEERING," WESTRAND, LONDON.

TELEPHONE NUMBERS—3663 and 8598 GERRARD.

## SUBSCRIPTIONS, HOME AND FOREIGN.

"ENGINEERING" may be ordered from any newsagent in town and country and at railway bookstalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months, payable in advance:—

| | |
|---|---|
| For the United Kingdom | £3 5 0 |
| For Canada— | |
| Thin paper copies | £2 18 6 |
| Thick paper copies | £3 3 0 |
| For all other places abroad— | |
| Thin paper copies | £3 3 0 |
| Thick paper copies | £3 7 6 |

Foreign and Colonial subscribers receiving incomplete copies through newsagents are requested to communicate the fact to the Publisher, together with the agent's name and address.

When foreign subscriptions are sent by Post Office Orders, advice should be sent to the Publisher.

## ADVERTISEMENT RATES.

The charge for advertisements classified under the Headings of Appointments Open, Situations Wanted, Tenders, &c., is four shillings for the first four lines, or under, and one shilling per line up to one inch. The line averages seven words. When an advertisement measures an inch or more the charge is 12*s.* per inch. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed. Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns of 2¼ in. in width. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

## TIME FOR RECEIPT OF ADVERTISEMENTS.

**Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity of going to press early with a portion of the edition, alterations for standing advertisements should be received 10 days previous to the day of publication.**

All accounts are payable to "ENGINEERING," LTD. Cheques should be crossed "The National Provincial Bank, Limited, Charing Cross Branch." Post Office Orders should be made payable at Bedford Street, Strand, W.C.2.

## AGENTS FOR "ENGINEERING."

AUSTRALIA: Gordon and Gotch, Limited, Melbourne; Sydney; Brisbane; Perth. Angus and Robertson, Limited, Sydney, N.S.W. T. Willmett and Co., Townsville, North Queensland. W. C. Rigby, Adelaide, South Australia Melville and Mullen, Melbourne, Victoria.

BELGIUM, Brussels: H. F. Satchell, 86, Rue du Tabellion.

CANADA, Toronto, Ont.: Wm. Dawson and Sons, Limited, 87, Queen Street East.

EDINBURGH: John Menzies and Co, Limited, Rose-street.

FRANCE, Paris: Boyveau and Chevillet, 22, Rue de la Banques For Advertisements, Office de Publications Commerciale, 167, Rue Montmartre, Paris (2e).

GERMANY: Hermann H. Fromm, Lützowstrasse 84, Berlin. W. 35. A Twietmeyer, Leipzig.

GLASGOW: William Love, 221, Argyle-street. John Menzies and Co., Limited, West Nile-street.

INDIA, Calcutta: Thacker, Spink and Co., Bombay; Thacker and Co., Limited.

ITALY: U. Hoepli, Milan. Anonima Libraria Italiana, Torino, and any post office.

LIVERPOOL: Mrs. Taylor, Landing Stages.

MANCHESTER: John Heywood, 143, Deansgate.

NEW ZEALAND: Gordon and Gotch Proprietary, Limited, Wellington, Auckland and Christchurch.

NORWAY, Christiania: Cammermeyer's Boghandel, Carl Johans Gade, 41 and 43.

ROTTERDAM: H. A. Kramer and Son, Limited.

SOUTH AFRICA: Central News Agency, Limited, Head Office—Johannesburg; and Pretoria, Cape Town, Port Elizabeth, Bloemfontein, Durban, and various branches and bookstalls throughout South Africa. Wm. Dawson and Sons (South Africa), Limited, 29, Long-street, Capetown.

TASMANIA: Gordon & Gotch Prop'ty, Ltd., Launceston: Hobart.

UNITED STATES: For Subscription, New York: W. H. Wiley, 440, Fourth Avenue. For Advertisements: J. S. Allan, 30, Church Street, New York.


## CONTENTS.


| | PAGE |
|---|---|
| Small Hydro-Electric Units (*Illus.*) | 339 |
| The Institute of Metals | 341 |
| A New Separately Excited Synchronous Induction Motor (*Illus.*) | 343 |
| The Denny-Edgecombe Direct Vision Torsion-meter (*Illus.*) | 345 |
| The Pretoria Municipal Power Station (*Illus.*) | 349 |
| The Lentz Variable Hydraulic Transmission Gear (*Illus.*) | 350 |
| 14-H.P. Gwynne Motor-Car Chassis (*Illus.*) | 351 |
| *Letters to the Editor.*—Tests of Water-Lined Furnace Boilers. Heavy Castings | 352 |
| Wolseley Motor-Repair Depot | 352 |
| Books Received | 352 |
| The Motor-Tug "Sparteolus" | 352 |
| Notes from South Yorkshire | 353 |
| Notes from Cleveland and the Northern Counties | 353 |
| Notes from the North | 353 |
| Notes from the South-West | 353 |
| Notices of Meetings | 353 |
| A Trade Union Opportunity | 355 |
| Power Alcohol from Tubers and Roots | 356 |
| Seaworthiness | 356 |
| The Institution of Mechanical Engineers | 357 |
| Counting the Atoms (*Illus.*) | 358 |
| Notes | 359 |
| The Large Water Tube Boiler | 360 |
| Geared-Turbine Paddle Tug for the Rhine (*Illus.*) | 361 |
| The Late Mr. G. F. Bonnor | 361 |
| The Late Mr. W. W. Bradfield | 361 |
| Labour Notes | 362 |
| Cutting Tools Research Committee (*Illus.*) | 363 |
| The Limiting Possibilities in Steam Plants (*Illus.*) | 366 |
| Peninsular and Oriental Liner "Razmak" | 367 |
| Wood Planing and Dovetailing Machines (*Illus.*) | 367 |
| The Influence of Lead and Tin on the Brittle Ranges of Brass (*Illus.*) | 368 |


*Four One-Page Plates.—MUNICIPAL POWER STATION AT PRETORIA, SOUTH AFRICA, AND MOTOR-CAR CHASSIS WITH 14-H.P. OVERHEAD VALVE ENGINE.*


# ENGINEERING.

*FRIDAY, MARCH* 20, 1925.


## A TRADE UNION OPPORTUNITY.

THE practices that the supporters of the Political Levy Bill alleged and sought to remedy are admittedly only part, and perhaps not the most important part, of the undesirable results which may be attributed to the trade union legislation of the last 20 years. The trade union movement includes elements that are hostile alike to trade and to union, and are found in it only in order to exploit its present privileges and immunities for the furtherance of political and non-industrial purposes. These elements cannot be expected to respond willingly to the appeal that has been made to trade unions themselves to put their own house in order. To industrial trade unionists, on the other hand, the present situation offers a remarkable opportunity, of which it is earnestly to be hoped that they will make full use. It is within their present power to procure for themselves a status they have never yet had, and to take a part that has never yet been open to them in bringing the collective power of all parties to bear on the promotion of their own industrial objects.

It is common ground that the recent legislation has created for trade unions a position of privilege beyond that of any other persons or bodies in the community. The benefits and immunities of such a position have not unnaturally attracted many persons who are not engaged in industry and have no desire to be so. They contemplate their cow in the spirit of Brer Rabbit: "'You do the pullin', Sis Cow,' sezee, 'and I'll do the gruntin',' sezee." The large majority of trade unionists are not of their sort; but the non-industrialists have an appetite and aptitude for grunting, and with the remainder of the active minority, whom they have deluded, address themselves to capturing the union machinery, and from time to time succeed in doing so. Their presence is doubtless a challenge to the genuine industrial unionists, or at least to the fraction of them that takes an active part in the proceedings of the union; and the direction in which the extraordinary powers of the union will be used at a given time, in the country or in any district, depends on which wing of the party happens for the time being to have got control of the machinery. The industrial unionists know perfectly well that large numbers of the non-industrial group or groups, and of those whom they influence, are absolutely unscrupulous in the use they make of their powers, and will use them as cheerfully in attempts to destroy the community from which the privileges were derived as to promote industrial interests. They must know, for instance, as well as engineers do, how during the war these men lost no opportunity of delaying the supply of munitions if such delay helped to enforce some claim that had been put forward on behalf of the men. It is, in fact, for the chapter of accidents that members must wait in order to learn whether on a particular occasion the trade union privileges are to be used to promote industrial objects and maintain personal liberty or to frustrate them. Industrial unionist leaders may well reflect that, courageous and indefatigable as they are in the struggle, the issues are too vital to the well-being of their constituents and the country to be left to the risk of such contests. The powers now in question have been tried, most fully and more than fairly. They have failed either to maintain industrial peace or even to assure their regular use for industrial objects. While they remain every proposal that is put forward in the name of trade unions has to be examined to see whether it is directed to an industrial, or a political end. The sincere co-operation of the genuine parties to industry is hampered and restricted because of the suspicion with which union proposals have to be scrutinised; and the unions return the suspicion with interest.

The chief mischief of the present trade union policy is that it ignores the change that has come over the policy of employers. All well-informed parties know now, what few or none recognised in earlier days, how intimately industrial groups, whether of manual workers or of whole industries, are members one of another, even when they are least aware of the fact. Yet an unwritten protocol, doubtless framed originally by politicians, seems to require that even attempts at co-operation shall necessarily take the form of trade-wide bargains or the decisions of tribunals. The easier and more rapid and effective method of obtaining industrial progress is to encourage the most advanced works to obtain the most effective results, and let the others, perforce, have to level themselves up to them. The use of this method, the introduction of the thin end of the wedge—the method by which Nature perfects her products—has been neglected or deliberately impeded. At the present time, when beyond all question the anomalous position of the trade unions has to be considered and rectified if the great national problems of production and employment are to be solved, industrial trade unionists have a chance beyond all precedent of assuring the future of their organisations and enlarging their scope.

If those who in trade unions represent the interests of industrial workers come forward and co-operate in repudiating the powers that have led to coercion or injustice, they will reap a rich reward. They will gain for the cause, to which they are devoted, the sympathy and co-operation of those who can assist them most effectively. Instead of being compelled to steer a politic course with an eye to essentially incompatible elements within their own camp, they will be able to show the courage of their convictions, and act with a single eye to the interests of the industrial community, which no one doubts that they have sincerely at heart. In the past they have sought power, because they believed that without it they could do nothing. The power they have gained is impersonal, and events have shown to demonstration that it can be seized by quite other movements than that for which it was sought and granted. What the trade unions need to-day

is less power and more influence. They can have no better illustration of how much influence can do without legal power than their own experience with the non-industrial partakers in their movement, who at one epoch, and indeed until recently, were the most potent force within it.

Trade unions cannot hope to remain permanently outside the laws that bind all other bodies of citizens. To themselves, no less than to the general body of industrial workers, any powers are dangerous that non-industrial influences can divert to political purposes, or use for constraining the conduct of individual workers by force. Their status as trustworthy associations for industrial and provident benefits must suffer if their numbers do not have the same unquestionable and automatic security against misappropriation of their industrial and provident funds for other purposes as are required of other insurance societies. Their influence both with their members and with the public will be discounted if the freedom and accuracy of their ballots can be questioned.

If trade unions will now seek to disclaim rights and immunities that no other bodies or individuals enjoy, and undertake obligations such as are enforced on all other bodies with purposes analogous to their own, they will do more than strengthen their own constitution and earmark their legitimate powers for their own industrial purposes. They will attract to themselves influence that will be worth more to the real interests of their constituents than the powers they surrender, and which in industrial matters can only act on behalf of a genuinely industrial body.

## POWER ALCOHOL FROM TUBERS AND ROOTS.

THE Fuel Research Board has published its Third Memorandum on fuel for motor transport, prepared by Sir Frederic Nathan, its Power Alcohol Adviser,* in which it deals in detail with the possibilities of using potatoes, mangolds or Jerusalem artichokes as raw material for producing power alcohol in this country. In addition to a survey of results obtained elsewhere, this memorandum gives an account of various experiments carried out in this country at various times from 1917 up to last year, with the object of determining the yield of the tubers and roots per acre and the production of alcohol to be obtained from them.

So far as concerns potatoes, the conclusion reached confirms that of the Departmental Committee on Industrial Alcohol, which reported in 1905 that a profitable industry could not be founded on the use of potatoes as a material for distillation. Since that date proposals have been made, as set out in the Report on Industrial Alcohol, issued in 1921 by the Commission of Inquiry into the Resources and Industries of Ireland, for the intensive cultivation of a potato of high starch content, and the distillation of alcohol in co-operation with the growers; but it is thought highly unlikely that such measures would have any real chance of commercial success. Even in Germany, where for some years before the war, alcohol was produced from potatoes on a large scale, the industry appears to have been successful only through the effect of a State subsidy. From furnishing 95 per cent. of the alcohol produced in Germany, its production has fallen to 15½ per cent., and the balance of opinion even in that country is that, while a greater use of alcohol as a fuel for internal-combustion engines is desirable, potatoes are too valuable as foodstuffs to be used economically for the purpose. On present wholesale prices for potatoes in this country, they would cost as raw material about 7*s.* per gallon of alcohol.

The prospect of mangolds is less hopeless. They are easier to grow, harvest and store, are not so liable to disease and failure, and their carbohydrates are in the form of sugar, and thus yield alcohol more simply than it can be obtained from the starch of potatoes. Mangolds would yield raw material at a little over half the cost of potatoes per gallon of alcohol; still not an encouraging basis for manufacture, even when allowance is made, as with all these products it has to be, for the use of residues in the manufacture of feeding-stuffs.

The most hopeful of the three crops is the Jerusalem artichoke, which in addition to its tuber below ground, has above ground a plant some 8 or 10 ft. high. It belongs to the natural order *Compositae* and is of the sunflower genus. It will grow in almost any well drained soil, can be left in the ground over winter without injury, and for a number of years will go on propagating itself from what is left in the ground without loss of yield, so that no labour is needed except for harvesting, until fresh fertilisers, or possibly at intervals fresh seed tubers, have to be applied. The yield seems to vary widely, and the chemical composition of the tuber is not the same in autumn as in spring, so that no very definite figures are given for the yield of alcohol per acre; but the considerable experience gained not only abroad but by experiments at the Royal Naval Cordite Factory and elsewhere concur in showing that it is better than is to be expected from the other crops. Experiments have been made and seem still to be in progress on the best conditions for its alcoholic fermentation; and it has been found, moreover, that when the carbohydrates are hydrolised and their concentration suitably reduced considerable quantities of a mixture of butyl alcohol and acetone can be obtained by the action of the *bacillus butylicus*, or by the simultaneous action of yeast with the bacillus a 70 per cent. mixture of ethyl alcohol with the mixed solvent. The residues from the distillation of the tubers seem to give about a ton of good feeding cake per ton of tuber, and the stalks of the plant when suitably treated yield about 12 per cent. of a pure and resistant cellulose, which is said to be very suitable for special purposes. It is interesting to observe that the average yield in this country —some 10 to 12 tons per acre—is higher than the figures given for Germany, Switzerland and the United States, though a little lower than yields obtained in France. The widest variation is in Queensland, where figures from 8 to 30 tons per acre have been obtained. Whether the discrepancies are due to the chemical or the bacterial contents of the soil, to the effect of sunlight or temperature, or to other circumstances, does not seem to have been determined.

The production of power alcohol is doubtless not the most immediate means to be taken in relief of the demand for fuel, and its most economical source may even be found ultimately in some of the luxuriant tropical growths within the Empire, at present best known as pests. Looking, however, at the fuel question, or questions, very broadly, the dominant fact is that almost all the fuel supplies at present used are what lawyers call wasting securities, in which trust investments may not be made, if at all, without considerable safeguards for getting out of them. As mineral fuels grow dearer, the advantage of fuels of vegetable origin must become accentuated, and those that can be obtained from crops which renew themselves once a year, or oftener, are particularly attractive from the economic point of view. It is therefore satisfactory to know that the subject of the production of power alcohol continues to receive attention, particularly when it is given in investigations as prudent and carefully conducted as are to be expected from the Fuel Research Board.

* Power Alcohol from Tuber and Root Crops in Great Britain. H.M. Stationery Office. 9*d.* net.

## SEAWORTHINESS.

THE points which have to be taken into consideration in the issuing of certificates of seaworthiness were yesterday discussed in a paper, read by Mr. B. J. Ives, before the North-East Coast Institution of Engineers and Shipbuilders. Mr. Ives quoted extracts from the British Acts (Merchant Shipping Act, Part V—Safety, and the Marine Insurance Act) covering the subject with the object of bringing out the definition of seaworthiness, from which it would appear that seaworthiness is not measured by an absolute standard, but is considered as a variable, expressing the state of the ship and the perils she has to meet in any situation.

Study of extracts from the Acts mentioned make it clear that seaworthiness is, under both these Acts, considered to be an attribute to the ship when the voyage commences, but the standard imposed depends upon the particular voyage on which the ship is to be employed. The test of seaworthiness imposed on a vessel sent on any particular voyage is that she is reasonably fit in all respects to encounter, not only the perils of the sea, but also to carry the particular cargo for the voyage.

The following factors have to be taken into consideration to secure the attribute of seaworthiness—structure, loading, equipment, the master and crew, provisioning and bunkering. Consideration of these factors at once shows that a ship may be in all respects fit for navigation and yet unseaworthy in relation to the cargo.

Classification indicates that a vessel classed in any particular society conforms with the standard of strength adopted and laid down by the rules of such a society; the certificate of classification embodies the principle that the vessel shall be in a fit and efficient condition for the safe conveyance of dry and perishable cargoes. A vessel to which a class has been assigned, and which class is maintained may in virtue of the same be considered seaworthy, but only in so far as those matters are concerned which come within the purview of the classification society. It must be remembered that the symbolic form of classification only represents the considered opinion of the society. Seaworthiness cannot therefore be defined as something which is altogether within the control of the society of classification; neither is it claimed to be, the responsibility of the classification society being confined to that which is embodied in its rules.

The case of the City of Lincoln may be cited as an example of the obvious fact that a certificate of the society of classification does not cover responsibility for the stability of a vessel. She loaded a cargo of hay and then took on 770 head of livestock, but the stowage was so arranged as to make the steamer top-heavy. The case reached the House of Lords which decided that the vessel became unseaworthy by reason of the method of loading before she left her loading berth, and that the shipowner was responsible in that he should have seen that more deadweight was put in the bottom of the steamer.

An important point arises in connection with latent defects. In cases of such defects the shipowner is liable for the consequence unless he is freed from liability for unseaworthiness by the terms of the charter party or bill of lading. In the case of the Guri Maru in 1923, the vessel lost one propeller blade, then a second, and on examination a third was found cracked. Eventually stouter cast steel blades were substituted for the broken ones. The charterers cancelled the charter, claiming damages from the owners for breach of undertaking as to seaworthiness. The judge was satisfied that the propeller blades were not constructed sufficiently strongly and were not reasonably fit for their work. One of the clauses of the charter party contained the exceptions, which included "Any latent defect, even if existing at the beginning of the voyage, in the hull, machinery, boilers or appurtenances." In the opinion of the judge the exception would exempt the shipowners if the defect could be proved to be a latent defect, but as it consisted of the absence of proper strength in the design of the blade it could not be termed a latent defect and was therefore a breach of the conditions to provide a seaworthy vessel.

In the matter of deck cargoes Mr. Ives quoted a case of part of a deck cargo of timber having to be jettisoned. The shipper claimed the value of the goods jettisoned from the shipowner on the ground that they were improperly stowed. In giving his ruling the judge said if a particular mode of stowage be conformable to the established usage of the trade it may not be improper, although another mode may be safer. *Prima facie* the deck was an improper place for stowage, the responsibility for such stowage resting on the master. The loss fell on the shipowner, the fundamental point being that perils of navigation were increased by the system of stowage adopted.

The master has implied authority to do whatsoever is necessary to make a vessel seaworthy. He is presumed to be acquainted with the ordinary

characteristics of goods carried as merchandise. On one important point legal evidence is somewhat lacking and that is the engine power necessary for seaworthiness. Insufficient engine power is a grave danger to a vessel; to be overpowered is also dangerous on account of the straining of the ship's bottom. Many builders and owners prepare and furnish for the use of those responsible for the handling of their vessels diagrams showing the effect of various methods of loading, knowledge which must be helpful in saving vessels from meeting with undue damage.

## THE INSTITUTION OF MECHANICAL ENGINEERS.

AN extra general meeting of the Institution of Mechanical Engineers was held on Friday last, at the Institution Building, Storey's Gate, London, under the chairmanship of Mr. W. H. Patchell, Past-President.

### CUTTING TOOLS RESEARCH.

Two papers were submitted, namely, a "Report on the Action of Cutting Tools," by Professor E. G. Coker, F.R.S., and "Experiments with Lathe Tools on Fine Cuts, and Some Physical Properties of the Tool Steels and Metal Operated Upon," by Mr. Dempster Smith, M.Sc., and Mr. Arthur Leigh, M.Sc. These papers constituted reports made to the Cutting Tools Research Committee of the Institution, and are reprinted, abridged, on pages 363 and 364 of this issue of ENGINEERING.

Mr. E. G. Herbert opened the discussion, and commented upon the value of Mr. Smith's work, as forming a link between the many series of experiments with heavy roughing cuts and the results obtained with light cuts, both well known investigations but entirely different in character. The papers showed that these two sets of tests overlapped. Translating the results in terms of temperature, the roughing cuts showed the durability of the tool to be somewhat restricted when the temperatures were high, and the tests with fine cuts indicated the variation in durability over the whole range, from nearly cold to red-hot. Many tools were used under conditions in which very little heat was generated, and the practice of hardening the tools and giving them a secondary heat treatment, made them have the power of withstanding high temperatures to which they would never be subjected, while it destroyed their durability at the low temperatures at which they were intended to be used. It was evident from the curves in the paper by Messrs. Smith and Leigh that the tool which had been hardened only was much more durable at the low temperatures or low speeds, than that which had received the secondary heat treatment, although the latter was more durable at the high temperatures. Probably the most striking fact brought out was that when a tool was cutting under conditions, which might be expected most to conduce to long life, such as a very small cut at a very slow speed, the durability was reduced more rapidly than under any other conditions, except those which produced excessive overheating. If the cut was increased, or if hot water was used, instead of cold, or if the water was dispensed with altogether, and the tool was allowed to heat by itself, the durability increased. It was justifiable to say that this was a temperature effect, and that the durability of a tool was low at low cutting temperatures. The explanation might be looked for in three directions—in the effect of temperature on tool steels, on the soft steels used for the work, and on the interaction between the tool and the work. Professor Coker had shown the effect of reducing the co-efficient of friction between the bar and the shaving by introducing a little oil, the result being to change the direction, and no doubt the magnitude, of the resultant of the principal forces. Considering the effect of temperature on the tool steel, Mr. Herbert referred to some hardness curves in Messrs. Smith and Leigh's paper, which, at first sight, seemed to offer a solution of the whole matter; they showed the relationship between hardness and durability. As the authors had pointed out, hardness did not, however, give an exact measure of the cutting capabilities of a tool. Dr. Stanton and Mr. Hyde, in a paper recently read before the Institution,* had shown similar variation in the vertical force, with changes of speed, as was shown in this paper, and they found that when they heat-treated their bar to normalise it, the effect entirely disappeared. Their conclusion—which he believed to be correct—was that the dip in the force curve was due to some effect of temperature on the soft steel of the bar. Dr. F. C. Lea, in a paper† read before the Institution in December last, showed that an alloy steel which was very ductile when cold, almost completely lost its ductility when heated to 300 deg. C., regaining this at higher temperatures.

He believed the same thing occurred with many other steels. This meant that steel at 300 deg. C. was "short," and thus, as was well known, was much easier to cut than ductile material. It was therefore possible if 300 deg. C. were generated in cutting that the resistance to cutting, the force on the tool, and the durability of the tool might be affected in the manner shown in the tests. The work-hardening properties of steel were affected by temperature in a remarkable way. Experiments made on a piece of the actual bar used by Messrs. Smith and Leigh showed that if the work-hardening number was expressed by 48 when the steel was cold, it fell to 12 at just over 100 deg. C. and increased again at higher temperatures. It might be taken that there were marked temperature effects, both with hardened and unhardened steels. He appealed to metallurgists to investigate the very important changes that took place in metals, particularly in steels, at the temperatures at which tools were used. An intelligent investigation of the problems was really dependent on the actual measurement of the temperatures. The authors had endeavoured to measure temperatures by the insertion of a thermo-couple in the tool. He also had tried this, and came to the same conclusion that such temperatures were unreliable because it was not possible to get the thermo-couple near enough to the source of the trouble. He had adopted another method, whereby the temperature was measured at its source, and he called the device "the tool-worked thermo-couple." This tool was made of a metal different from that being cut; when cutting steel he used a stellite tool. For the thermo-couple the tool and metal served and the tool was insulated from the slide rest of the lathe with mica. He had good reason to rely upon that device for measuring temperatures, and he hoped it might prove of value in finding solutions for many of the problems raised in the paper.

Dr. T. E. Stanton explained that the work of Messrs. Smith and Leigh upset many of the old rules for economical cutting. In this connection he directed attention to a book by Commander P. Denis in which very precise rules for the most economical speeds of cutting were laid down, but which did not seem to have any association with the results obtained in experimental work.

Mr. R. C. Macdonald discussed the effect referred to by Professor Coker, in his paper, that after a cut had been made and the tool run back it was sometimes found that the point of the tool was not in contact with the work and he showed forms of tools which could be used to reduce and even to prevent the action. The authors of the two papers seemed to differ as to lubrication, one contending that lubrication was beneficial and the other that it was not much use. He thought that general experience with roughing cuts showed that the lubricant was not of much assistance. Mr. Dempster Smith had mentioned that the steel cut had a carbon content of 0·35; that was a fairly high carbon content, and he asked Mr. Smith if he considered that the same results would have been obtained with a lower carbon content, such as in the case of ordinary mild steel. Before the introduction of special tool-grinding machines, the lazy workman was apt to grind his tool away and get a big rounded edge at the corner. This tool threw a good deal more stress on to the machine, and therefore a great deal of power was required to drive it.

Mr. R. W. Bailey said that he regarded both papers from the works point of view. He was interested in Professor Coker's method of examining stresses, particularly in regard to depth of penetration of the stress with heavy cuts on, say, heavy shafting, and would like to know the extent to which the material was damaged. The ordinary test to determine the fatigue strength of metals was made on such small specimens that it was difficult to draw a parallel between a shaft which had been roughed out very heavily and a test piece which had been turned up under different conditions. Mr. Herbert, he said, had raised the question of metallurgical research to show the effect on the qualities of metals at temperatures up to 300 deg. C., in which connection he (the speaker) referred to the difficulty of finding the exact effect of heat upon the metal. He had experience of the development of brittleness in material and had made tests in which brittleness was produced; yet the microscope had failed to show why the brittleness occurred. Considering the metal used in Mr. Smith's tests, it appeared that the maximum hardness for the carbon steel was in the region of 40, whereas for the alloy steels the hardness maxima were in the region of 60–70. The figure 40 for time-hardness number corresponded, in a test referred to by Mr. Dempster Smith, to the Brinell number of 400, a very ordinary hardness; he would have expected the tool hardness to have been in the region of 600 Brinell. In the works fine cuts were not used, except in the case of very hard materials. The steels experimented upon by the authors were medium or ordinary mild steels. While the authors' diagrams threw light on the behaviour of the tool for low speeds and small cuts, there was a field to be examined—speaking from the practical point of view—in which the same tools would be applied to the harder materials. It appeared from the diagrams that the plain hardened tool, without any heat treatment, performed best on mild steel, and this was quite in accord with what happened in some cases of hard steels he had experience with.

Mr. F. E. Robinson asked Professor Coker whether, in his experiments, the milling cutter was of the plain type or whether it had any spiral on it. It would be of interest to know if there was any difference in the stresses with the two types of cutters. He was much interested in the curves shown in Messrs. Smith and Leigh's paper. These seemed to offer great possibilities of practical application in the works. The steel chosen—a 0·35 carbon steel—was in common use, and, although he had been unable to obtain any verification for the results with that particular grade of steel, he had obtained some results in the case of a B.E.S.A. steel of about 0·25 carbon content—ordinary black-rolled mild steel. He had found, in this case, that the cutting speed was much higher than the figure given by Mr. Dempster Smith. When using a steel containing 18 per cent. of tungsten and hardened at 1,250 deg. C., tests were conducted at a cutting speed of 167 ft. per minute, the feed being 0·009 in. per revolution. The diameter of the work was 2¼ in. and the depth of cut 0·078 in. The actual life of the tool was found to be five hours. These results were obtained from day to day. Unfortunately, the steel was not comparable with that used by the authors. His own experience was that an 18 per cent. tungsten steel gave the best results when hardened at about 1,250 deg. C. and not tempered at all. With the same steel, hardening at 1,320 deg. C. and tempering at 575 deg. C., and in other respects working under the conditions already mentioned, resulted in the life of the tool being less than one-third of the above-mentioned figure. In another test, he had attempted to follow up the investigations at one of the cutting speeds given by Mr. Dempster Smith, namely, 120 ft., with a higher carbon steel, 0·5–0·6. He hoped later on to send in some further results to the Institution, the job being one which would be running for a considerable time. It was found that the tools, hardened as Mr. Smith had hardened his tools, would not stand up at all. In a great deal of repetition manufacture light cutting was the customary practice.

Mr. Dempster Smith then replied to the discussion, so far as his own and Mr. Leigh's paper was concerned. With reference to Mr. Robinson's observations, he said, that as between exceptionally light cuts and heavy cuts the circumstances were

* See ENGINEERING, current volume, page 150.
† ENGINEERING, vol. cxviii, page 816.

quite different. The conditions of temperature and the secondary heat treatment, with tools taking cuts of $\frac{1}{16}$ in. did give the roughing tool an improved durability of something like 12½ to 15 per cent. With extremely light cuts, so far as the steel used in the experiments was concerned—old shell steel—the case was different. The carbon contents were not uniformly distributed. While the carbon content was given in the paper as 0·35, the steel was segregated at spots, resulting in a eutectic steel having 0·9 carbon. Steel in the neighbourhood of 0·9 carbon had a very destructive effect on the cutting edge of a tool; the slag destroying it. Some two years ago he had started operations on ordinary mild steel of 0·25 carbon content, but in the recent tests the aim was to get something fairly hard in order to destroy the cutting edge, and it was believed that it would be uniform in action in this way. Mr. Robinson's figures were very satisfactory; the 18 per cent. tungsten steel gave a result much superior to that of the 14 per cent. tungsten one used in the experiments recorded in the paper. He agreed with Mr. Bailey that there was room for criticism of the hardness of the carbon steel; it did appear too low, and he proposed to go over the test again. In reply to Mr. Macdonald, the 0·35 carbon steel was not uniform in character; otherwise the durabilities would have been higher. A cooling medium had the effect of carrying away the heat and was exceedingly useful when operating with heavy cuts, thereby improving the cutting speed by about 15 per cent. Dr. Stanton had raised an important point in relation to Commander Denis' book. The speaker had been unable to find Commander Denis' experiments, however, and could not therefore dispute them. It had been stated that the use of a lubricant might increase the cutting speed, but this was contrary to all experimental evidence produced in this country for heavy cuts. The speaker was interested in Mr. Herbert's remarks on the use of a thermo-couple, and hoped he might have an opportunity of seeing how it worked. He had tried a thermo-couple with an ordinary steel tool and did not get any consistent results.

Professor E. G. Coker then replied to the remarks relating to his paper. He appreciated Mr. Herbert's attempt to get the temperature right at the point of the stellite tool. In reply to Mr. Macdonald's criticism, he said that practically all the tools used were arranged so that not only was the tool supported right to the end but, in order to keep it up to its work, there was a strut underneath, so that it should not be deflected by a purely bending action. Even so, there would be a small amount of bending in the wedge-shaped tool, and to measure that accurately a small galvanometer mirror was put on at one side, by which an estimate was obtained of the actual amount of the downward spring. That done, there was still an amount left which gave the difference between the point of the tool and the work. If the angle of the tool were altered, of course it might not be obtained at all. He did not think there was any difference in views between himself and the authors of the other paper on lubrication effects, but he held to his view that when the "bow wave" was so pronounced as it appeared to be, there would be permanent distortion of the material underneath the tool, whereas when the curve went back in the way shown with lubrication this deformation would not occur. He had made no efforts to determine systematically the actual depth of the stresses in the material. Of course if a tool was not cutting properly there would be overstress, but when a tool was cutting very smoothly and taking off material by a pure cutting action there would be practically no ill-effect at all. In answer to Mr. Robinson, he stated that the milling cutter used had no spiral, but was perfectly straight. Had there been a spiral, the shavings would have been twisted out sideways, and it would not have been possible to study the effect of the cut so well; there would have been a complicated colour effect.

The chairman concluded the proceedings by announcing an ordinary general meeting to be held to-night at 6 p.m., at which the Second Report to the Marine Oil Engine Trials Committee will be presented and discussed.

## COUNTING THE ATOMS.

IN opening the third of his series of four Royal Institution lectures on "The Counting of the Atoms" last Saturday, Sir Ernest Rutherford said that last time he had dealt with estimates of the number of atoms in any given weight of material based upon the Brownian movements and upon the scattering of light by the molecules of the air. A member of the Royal Institution had afterwards asked him why a gas molecule scattered light, and he would try to explain this. In accounting for the blue light of the sky, Rayleigh had shown in a general way that any particles optically denser than the surrounding medium would set up secondary waves. That effect would be quite independent of the constitution of the molecules; all that was required was differentiation of the molecules. The problem had recently formed one of the tripos examination questions: assume the molecules of a gas to be electric doublets, what would be the amount of the scattering and of the polarisation? Imagine, Sir Ernest said, a train of waves of light, the electric forces involved would be vibrating at right angles to the direction of the propagation and the magnetic forces again at right angles to the electric forces. The electric forces would separate the doublets into positive and negative particles, and these particles would move axially to and fro and set up a secondary disturbance in a definite direction with very little disturbance at right angles to that direction. An electric doublet was really a Hertzian oscillator.

The theory of scattering had been verified by laboratory and other experiments, notably by the present Lord Rayleigh, who had shown that all the common gases scattered light in amounts of the right order of magnitude, and that this light was completely polarised at right angles to the ray in the case of spherical gas particles, but incompletely polarised in the case of non-spherical, asymmetrical molecules. With oxygen, about 95 per cent. of the light was polarised. In his most recent researches, J. Cabannes had experimented with different gases in transparent tubes exposed to sunlight. He photographed the diffused (scattered) light with long exposures, sometimes of several hours. The photographs thus obtained showed two diffused beams—the stronger normal to the beam, the weaker parallel to it—and weak diffusion in the light gas hydrogen, stronger diffusion in air, and strongest in the heavy-gas carbon dioxide (Fig. 5). The very slight diffusion observed in a vacuum tube became stronger as air was admitted into the tube. The two spectra of the diffused and the incident light showed that the diffusion increased towards the violet end of the spectrum, being inversely proportional to $\lambda^4$, as Sir Ernest had pointed out in his last lecture (page 327 *ante*). Cabannes also found that the asymmetry of the molecule decreased the polarisation, and in his bold deduction of Avogadro's constant from these researches he had worked out the value $6{\cdot}9 \times 10^{-10}$.

Regretting that he had no time to describe the methods depending upon the emission of particles from hot bodies, the lecturer passed to the most important and accurate estimation of Avogadro's number by means of the determination of the unit of electric charge. These researches had proved that electricity was itself atomic in character and that every quantity of electricity was an integral multiple of a definite unit, no fractional values being met with. To explain the significance of that statement he would have to run through the theories of electricity. According to Franklin's single-fluid theory, a body was filled with an imponderable electric fluid, of which a positively charged body contained an excess and a negatively charged body a deficiency; the terms positive and negative electricity were introduced by Franklin. But neither this single-fluid theory nor the double-fluid theory of Symmer and others, although useful in discussing some electrostatic experiments, really explained the nature of electricity, until Faraday, in 1833, proved that there was an extraordinarily simple relation between the quantity of electricity passing through an electrolyte and the atomic weight of the element deposited (or dissolved). Faraday found that the unit current deposited always one equivalent of any element. That equivalent was the same as the atomic weight for hydrogen and the monovalent atoms; it was half that weight for copper (divalent) and a quarter for tin (tetravalent). That constancy implied that electricity was conveyed by carriers (ions) in multiples of a unit charge, that of the hydrogen ion.

Everybody, it might be thought, should at once have seen then that electricity was atomic. But the full significance of the law of electrolysis was not grasped because Faraday was interested in the effect of the electricity on the medium surrounding the wire, and Maxwell had similar interests. The first who recognised the bearing of the law was Johnstone Stoney, who drew attention to the ion as an important constant before the British Association, 1874, in a paper which was only published in the Philosophical Transactions of 1881. Stoney's estimate of the electrochemical equivalent was, however, only a sixteenth of its true value. Maxwell admitted the atomic character of electricity, but could explain his problems without it. Helmholtz, in his Faraday lecture to the Chemical Society, in 1881, devoted a few lines to that aspect; later physicists took the atomic character for granted. But the results of electrolysis were complex, and the driving force for the modern researches came only with the discovery of the ionisation of gases by radiations and the deflection of cathode rays by magnets. In electrolysis, the relations were the following: if M were the mass of the hydrogen atom, E its charge, N the number of atoms per gramme; then NE was found to be equal to 9,650 electromagnetic units. NM was 1 gramme, hence, by division, E/M =9,650; if E could be determined, then N could be deduced.

Now Townsend proved in the Cavendish Laboratory (1900), that the charge carried by a gaseous ion (produced by cathode rays) was equal to the charge on a hydrogen ion in the electrolysis of water. If the ion exerted a partial pressure like an ordinary gas molecule, then for N ions (molecules) per cubic centimetre of gas, each carrying a charge $e$, $Ne$ would be $3 \times 10^8$ K/D, where K was the velocity of the ion in the gas under a gradient of 1 volt per centimetre, and D the coefficient of diffusion of the ions in the gas; the K and D were measured. In electrolysis the charge was $e^1$, and it was known that $Ne^1 = 1{\cdot}22 \times 10^{10}$ electrostatic units; by division we obtained $e/e^1 = 0{\cdot}0246$ K/D. Thus the two charges $e$ and $e^1$ were linked up, and substituting the values found for K and for D, $e/e^1$ turned out to be nearly 1, or $e = e^1$. A direct determination of $e^1$ had been attempted by Townsend in 1897, in the following way: He had observed that the gases liberated by the electrolysis of water (sulphuric acid or caustic potash) carried charges with them, a large proportion of which remained on the gas after it had been bubbled through a liquid and filtered through glass wool to remove the spray. The charge, *e.g.*, on oxygen, proved to be sometimes positive and sometimes negative, and would change with the experimental conditions and even in the course of the experiment; the phenomenon, Sir Ernest remarked, was not yet understood.

Townsend further noticed that when the gas was bubbled through water, a cloud of a whitish mist formed above the water, but only when the gas was electrically charged, and that the weight of this cloud was proportional to the charge on the gas. Sir Ernest demonstrated the easy production of the cloud. In the Townsend apparatus, the oxygen (or hydrogen) was bubbled through potassium iodide and water, and the cloud introduced into a paraffin block and further bubbled through sulphuric acid to be dried; the gas then entered a flask lined with tinfoil, which was joined to an electrometer. It was thus demonstrated that the dried gas retained its charge and was capable of raising a new cloud when bubbled through water. In other experiments, the clouds were collected in flasks, and the rate of settling of the cloud was watched by taking photographs at intervals of a few minutes; from the rate of settling the actual size of the drops was estimated by Stokes' law. The condensed water being weighed, the $m$ in the ratio $e/m$ was known, and $e$ was found (in the improved experiments) to

be $4 \times 10^{-10}$ which was not much too small. Sir Ernest demonstrated Stokes' law by letting lead shot sink in glycerine, in which the heavy shot fell rapidly and the fine shot slowly; by this method the viscosity of the medium (glycerine) could be determined.

But there was no certainty that the $e$ so measured was the unit, and not a multiple of it. About the same time, C. T. R. Wilson observed that ions became the nuclei of condensation when moist air was suddenly cooled by expansion and J. J. Thomson utilised this method to determine the charge on clouds settling between charged electrodes. Then H. A. Wilson experimented with positively and negatively-charged drops between charged plates. Rough estimates of $e$ were made by these and other methods applied elsewhere; but they were only qualitative. The difficulties were enormous because the drops were not uniform in size and for other reasons. Repeating these various experiments, Millikan (Chicago) recognised the necessity of working with single drops, which he

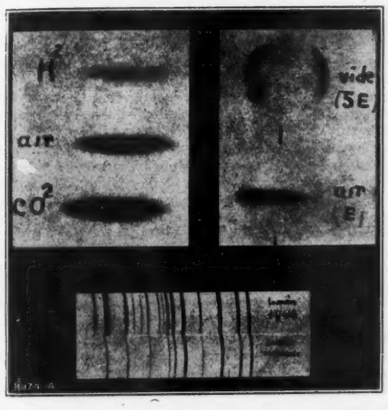
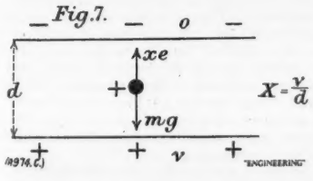


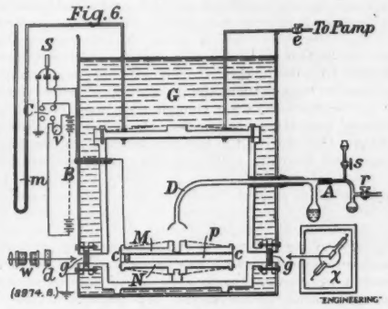

FIG. 5.

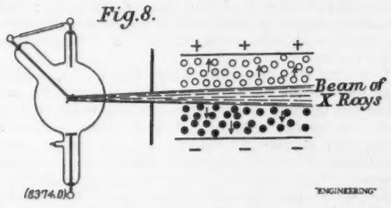



obtained in the apparatus illustrated (in its final form) in Fig. 6. Droplets of oil or mercury were forced through glass wool and a tube into a dust-free chamber, containing an air condenser MN, the large brass plates of which were charged to several thousand volts. When a drop carrying a small charge had entered the condenser through the hole at the top, the hole was closed, and the drop observed with the aid of a microscope and cross hairs. If the droplet carried the positive charge $e$ (Fig. 7), then it would, in the electric field X, be urged upward with a force Xe and downward by gravity with the force $mg$; if the drop were kept floating between the plates by adjusting the field, Xe must be equal to $mg$. The apparatus was then elaborated, as indicated, so as to enable the droplet to catch up ions from the residual gas in the condenser, while suspended in the field, and further measurements made. A droplet of, say, 0·0065 cm. radius, could be kept floating for minutes and even for hours.

To produce these ions, an X-ray bulb was placed outside the chamber C, sending a beam of rays horizontally into the space between the condenser plates; the light of an arc lamp was concentrated on the particle through lenses $w$ from the other side, and the whole chamber was provided with an oil-jacket so as to keep the temperature constant and avoid convection currents. The beam of X-rays would ionise the gas between the plates, and when the condenser was charged (as in Fig. 8), the ions would be separated and attracted or repelled by the plates, which they would approach at high velocities. When the velocity was not too high (*e.g.*, immediately after switching off the field), the droplet might catch an ion by collision, and thus increase or decrease its charge and change the rate of its own fall under gravitation. If the charge on a drop of mass M were E and the velocity of the drop under gravity $V_1$ and under the field X were $V_2$, then $V_1/V_2 = mg./$ (X E $-$ $mg$,) or $E = \frac{mg}{X}\frac{(V_1 + V_2)}{V_2}$. If the charge were lowered from E to $E_1$ and the velocity changed into $V_3$, then the loss of charge $E - E_1 = \frac{mg}{X}(V_2 - V_3)$; the velocity difference $(V_2 - V_3)$ was measured in cm. per second.

In a very large number of experiments made by Millikan and his collaborators, this velocity difference was always found to be about 0·0089 or a multiple of that figure. The charge captured was, therefore, always a unit, and it proved possible to reduce multiple charges one by one down to a unit. Sir Ernest demonstrated the method in the way Mr. Coolidge had shown it to him last autumn, after the Toronto meeting of the British Association. His condenser consisted of two horizontal plates of sheet metal, about 9 in. apart, the upper one of which was charged from a Wimshurst machine to about 4,000 volts. Between the plates was sus-




pended a disc of aluminium, representing the droplet; the suspension was by a thread and beam, counterpoised outside the condenser. The air in the condenser (which was not enclosed) was ionised either by a wire on which a film of polonium was deposited, or by an X-ray bulb. The wire was introduced into the condenser; when it was held above the disc, the disc moved up, when held underneath, it moved down. The X-ray bulb was placed behind a lead screen provided with two horizontal slits, and the bulb was raised up or lowered so as to be in the plane of the upper or the lower slit; thus the air above or below the disc was ionised, and the disc moved as just mentioned.

In this way it had been definitely established that electricity was atomic and the unit charge $e = 4{\cdot}774 \times 10^{-10}$ electrostatic unit, the Avogadro constant $N = 6{\cdot}062 \times 10^{23}$, the number of gas molecules per c.c. at 0 deg. C. and 760 mm. $n = 2{\cdot}703 \times 10^{19}$ and the mass $m$ of the hydrogen atom $1{\cdot}662 \times 10^{-24}$ gramme. But the difficulties caused by evaporation of the drops, by convection, by viscosity, &c., were enormous, and the determinations would be repeated. Stokes' law, moreover, was found to require modification for very small particles, and after all, a more direct method of estimating the atomic dimensions might be desirable. With that, Sir Ernest concluded, he would deal in his next lecture.

---

AWARD OF ROYAL GOLD MEDAL FOR ARCHITECTURE.—It is announced that H.M. The King has approved the award of the Royal Gold Medal to Sir Giles Gilbert Scott for the excellence of the latter's work.

## NOTES.

### A NOTABLE AEROPLANE FLIGHT.

What we believe is the longest flight so far carried out for purely official or business purposes was completed on Tuesday last when Air Vice-Marshal Sir Sefton Brancker, Director of Civil Aviation, landed at Croydon Aerodrome, after having travelled by aeroplane from London to Rangoon and back, a journey of roughly 17,000 miles. The machine, a D.H.50 fitted with a 230-h.p. Siddeley-Puma engine, left the Stag-lane Aerodrome of the De Havilland Aircraft Company, Limited, on November 20 last, and proceeded by way of Cologne, Berlin, Warsaw, Bucarest, Constantinople, Baghdad, Karachi, Delhi, and Calcutta to Rangoon, where it arrived on February 6. The same route was followed on the return journey, which was commenced on February 8, as far as Bucarest, whence the machine travelled to London *via* Vienna and Paris. The main object of the journey was to enable the Director of Civil Aviation to survey the possible air routes in the Near East and in India, and numerous stops were made *en route* for the examination and discussion of various matters connected with the development of aviation. It is interesting to record, however, that no delays due to breakdowns of the machine were experienced, and that the same engine was employed throughout, all necessary spares being carried on the machine, a circumstance on which the designers of the aeroplane and its engine, as well as the pilot, Mr. Alan Cobham, must be congratulated. The number of hours in actual flight amounted to about 200, the engine usually running at 1,250 r.p.m., and giving an air speed of from 85 m.p.h. to 90 m.p.h. The petrol consumption, we understand, was about 12½ gallons per hour.

### WAR-OFFICE SPECIFICATION FOR MOTOR VAN.

The War Office has published a complete specification for a pneumatic-tyred chassis suitable for a 15-cwt. van or a four-stretcher ambulance body. This chassis is not the subject of a War Department subsidy, but is of interest to the general public in that the specification calls for a strongly built vehicle comparable in performance, and to some extent in constructional detail, with the subsidy-type light lorry. The new specification is generally very similar to that for the 30-cwt. subsidy-type vehicle which we discussed in some detail in our issue of July 25, 1924. The majority of the comments that we made at that time are applicable to the specification just issued, and it is therefore not necessary to repeat them here. The points of most importance in the specification are those having reference to cooling, brake power, and clearance. A radiator of the vertical straight-tube type, with detachable top and bottom tanks, is again specified, and it is also stated that provision must be made to allow the cooling capacity of the radiator to be reduced for use in cold climates. It would have been helpful if the acceptable provision for this purpose had been defined in detail, as a number of cosies are now in use which fulfil this condition, but can hardly be regarded as satisfactory from a mechanical standpoint. The braking tests to be applied are identical with those for the larger vehicle. The actual ground clearance is not specified, but the tests to which the vehicle will be subject are such as would incapacitate a chassis in which the clearance was inadequate for any condition likely to be met with in practice. An important point is that the chassis must be a self-contained unit capable of being driven without the body, and no fittings must be in any way dependent on the latter.

### CONDENSER TUBES.

We have frequently dealt in these columns with the problem of condenser-tube corrosion. The problem is again raised in a paper on "The Manufacture of Brass Condenser Tubes, with Some Notes on an Alternative Alloy," read on the 10th inst. before the Institution of Engineers and Shipbuilders in Scotland by Mr. G. H. Whiteman and Mr. A. Spittle. This paper mentions the corrosion difficulty in a casual way only, but by drawing attention as it does to the extreme care displayed in every phase of

brass condenser-tube manufacture, and to the great stringency of the specifications and tests, it indirectly gives marked prominence to the actual seriousness of these troubles. The brass tubes consist of electrolytic copper having a degree of purity of 99·9 per cent., alloyed with spelter containing 99·5 per cent., or, better, 99·9 per cent. of pure zinc, and tin having a purity of 99·75 per cent. Most minute attention is paid to the processes of manufacture of the tubes from start to finish; notwithstanding this, brass condenser-tube failures still occur, and some are of a grave character. As an alternative to brass, the authors mention alloys tougher than brass and containing no zinc, and make special reference to cupro-nickel which, they add, has justified its adoption so far. A power station in the North of England had been notorious for the rapid destruction of brass condenser tubes. It adopted three years ago 80/20 cupro-nickel tubes, and no failure has yet been recorded. All the new condenser installations of the power station in question are being fitted with cupro-nickel tubes. The authors further state that upwards of 16 ships are already using, or are about to be fitted with cupro-nickel condenser tubes, including two Atlantic liners which are being entirely re-tubed with them. The manufacture of the cupro-nickel tubes presents difficulties different from those appertaining to brass, but, as the authors rightly add, should they prove more enduring than brass—as there is every likelihood that they will—their extra first cost will be much below the first cost of brass tubes plus the expenditure of renewing the latter repeatedly as they fail.

### MATERIALS FOR RUBBER COMPOUNDING.

In a paper on "Modern Materials used in Rubber Compounding," read before the Institution of Rubber Industry on the 2nd inst., Dr. A. A. Somerville, of the R. T. Vanderbilt Company, Incorporated, dealt in detail with the results of his own experience and experiments. Clay, he pointed out, remained the cheapest material for stiffening rubber, which was not the same thing as hardening it; but only the highest quality clay should be used, and chemical analysis was no guide. Ordinary carbon black had in the last few years found a rival in "thermatomic carbon," which was prepared from natural gas, not by combustion, but by cracking at 2,000 deg. F. The cracked gas was filtered through cotton bags, and thus a graphitic carbon was obtained, the yield being higher than by the old process. There were a hundred factories of this thermatomic carbon on the large natural gas field of Louisiana, and the production, 1 million lb. in 1923, had become four times this in 1924, and would be many times greater this year. Thermatomic carbon did not stiffen the rubber, nor retard its curing as carbon black did, and it could be added in much larger proportions (300 per cent. instead of 30); 1 lb. of it replaced 3 lb. of zinc oxide as activator, and it was much cheaper; the two kinds of carbon were useful, each in its own way. Fast organic colouring matters had become very popular, but only because they could be combined with organic low-temperature accelerators at low cost. Dr. Somerville gave some particulars about the use of tetramethylthiuram disulphide, by the aid of which, and of steam at 20-lb. pressure, quick curing could be effected in five minutes, but which could also be used in curing at higher pressures or in hot air if the article in question—steam hoses, parts of valves, &c.—had to stand severe treatment. He further showed forty metallic salts of the dithiocarbamic acid which he had prepared both in the ordinary and the oxidised states, the latter being more suitable for extreme conditions. The metals included gold, platinum and the rare earths, and even copper, arsenic and mercury, which rubber chemists generally avoided. Activated with zinc oxide these salts served also as accelerators, and with the barium and strontium salts lime could be used. The latter was in America preferred to magnesia, which was common over here. Dr. Somerville spoke in favour of combining several compounding materials and accelerators; he would not use many together, however, and one cannot but feel that the complications of the chemistry would make very careful and prolonged ageing tests essential. Though some of Dr. Somerville's compounds could be applied in very small percentages, they were mostly mixed with 4 per cent. of sulphur, which is above the average; but his studies did not concern hard rubber.

## THE LARGE WATER-TUBE BOILER.*

By PHILIP WARWICK ROBSON, O.B.E., M.Inst.C.E.

*General Aspects of the Problem.*—The author draws attention to the disparity between the present size of turbine units and that of boiler units for large powers. He contends that, given security of service from a boiler plant, the same arguments which justify the use of large turbine units also extend to boilers. He draws attention to the fact that large modern power stations in the United States and in France are equipped with much larger boiler units than are at present being considered in this country. He attributes this tendency to the fact that in the two countries named electric power supply is provided chiefly by private enterprise, as against the much more general system of municipal control which is usual in Great Britain, and he traces to this circumstance not only a social and political difference as between the two methods, but also a considerable technical effect. A municipal engineer is overborne in attempting new developments, whilst in the case of private enterprise the ultimate benefits are weighed directly against possible risks, and a decision is taken on the strict merits of the case, without fear of public criticism of the technical officers concerned. It is also pointed out that the conservatism which is imposed in the case of British undertakings by the circumstances referred to also makes it difficult for new manufacturers to engage upon the production of boiler plant for power stations, even though they may have real technical improvements to offer. It is unquestionable, however, that during the last few years there has been a new and growing spirit amongst those responsible for electricity undertakings, in respect of interest in the boiler plant as being the foundation of the successful working of the station; and the author foresees in this development that this country will not be allowed seriously to lag behind its international competitors, which, in connection with power supply, may be in a position of greater freedom to adopt improvements and to encourage development. It is possible on official authority to predict a four-fold growth in the boiler power of this country during the next 10 years; and as cheap power is essential to national prosperity, the problem of boiler-room efficiency is of far-reaching importance.

*Technical Problems of the Large Boiler.*—The author then reviews the relation between duty, capacity, and efficiency in large boiler units, and contends that in order to construct boilers of large capacity within reasonable overall dimensions full advantage must be taken of recent improvements in boiler design whereby it is possible to increase the evaporative duty by 50 per cent. Consideration of the bearing of these improvements, in relation to both boiler and furnace, leads up to the following statement of the requirements to be met in the design of large boiler units:—

(1) The design must be suitable for use in boilers of 100,000 lb. to 300,000 lb. of steam hourly capacity.
(2) There must be positive immunity from tube troubles and from priming at high duties, and there must be likewise high efficiency.
(3) The design should preferably be best suited for ultimate high working pressures of 500 lb. per square inch and upwards.
(4) Boiler and furnace must be suitable for long steaming periods without stoppages from minor causes.

*Types of Boilers Suitable for Large Units.*—Well-known types of boilers at present used in large power stations are then dealt with. The methods of overcoming their proved limitations are considered critically, and reasons for tube troubles and tendency to prime are established in such a way as to indicate the remedies. There is ample evidence to show that, if available knowledge and experience are properly utilised, there are no practical difficulties in constructing large boiler units of the kind referred to in the previous paragraph. The question of the respective merits of boilers of the sectional type, in which tubes are connected to headers as against those with tubes connected to drums is closely examined, the conclusion being reached that it is well for both types to develop side by side until a more decisive stage is reached. The Yarrow boiler, as applied for land work, is dealt with.

*Furnaces and Grates.*—The author refers to recent developments in wide stokers and to high-duty grates which are essential to the development of large boilers. The function of the furnace in relation to efficient combustion is also considered, and the necessity of proper and ample proportions of furnace is emphasised. The weaknesses of furnaces are cited, together with reference to appropriate remedies. The examination covers stokers of the travelling-grate and retort types. By properly applying these well-known devices there appears to be no reason why boiler units of the largest kind should not be constructed.

*Pulverised Fuel.*—In connection with the use of pulverised fuel the author visualises the possibility that by its means the whole science and practice of steam-raising from coal may be revolutionised. As powdered fuel and air can be closely intermixed as they enter the furnace, it becomes possible greatly to reduce the amount of excess air required to guarantee complete combustion, and this renders the system of burning powdered fuel highly efficient. The present encouraging developments have been devised by combustion engineers, who have adopted special furnaces to existing types of boilers. The author gives reasons for suggesting much further advance when the co-operation of boiler constructors is secured to build boilers best suited for the purpose. The addition of pulverising plant to a boiler house adds to a plant already extensive and complicated. There is no saving in the method of coal storage or in the amount of coal-handling plant required, and the pulverising plant is a substantial addition thereto. There is no reason why each boiler house should contain its own pulverising plant. With the establishment of public service pulverising plants, with suitable tank wagons for the transport of the powdered fuel, and with the requisite modifications in fuel-storage and fuel-handling arrangements at the boiler house, the application of powdered fuel assumes a simpler character altogether. The general application of powdered coal for steam-raising is not, therefore, merely a new kind of furnace and stoker. It is a system which, if developed logically, will revolutionise the whole manner of dealing with coal for electric-power purposes from the colliery onwards. The final effect, according to this broad plan, will be to facilitate the introduction of large boiler units and to increase the efficiency of boilers of all sizes, to eliminate the present cumbersome forms of coal- and ash-handling plants, and generally to make substantial reductions both in the first cost and subsequent upkeep cost of boiler plants.

*Conclusions.*—Many experienced engineers in this country consider that a boiler unit of 100,000 lb. hourly evaporative capacity is the largest size which can be wisely adopted. The author doubts the rightness of this conclusion, and suggests that it is impossible to suppose that boilers can be made an exception to steady growth in size so long as larger and larger turbine units continue to be demanded. On the score of capital costs the use of large boiler units means saving in space occupied and, therefore, in the cost of buildings; there are, also, fewer valves and fittings, less piping, conveyors, &c.

The problems surrounding the introduction of very large boiler units are of too important a character to be assumed alone by those responsible for any one station. The whole conception of the large boiler unit requires to be examined and reviewed under conditions in which the widest knowledge and experience should be pooled. This is only possible by setting up a Technical Committee constituted in such a way as to have the countenance of the Electricity Commissioners on the one hand, and the complete confidence of those who are responsible for large power stations on the other. Some such course as this would relieve any one electricity undertaking from the necessity of making departures or experiments which might not be approved generally. The lines along which progress should be made would be settled impartially, and in this way the public interest would be best served.

* Paper to be read before the Institution of Civil Engineers on Tuesday, March 24, 1925.

PRODUCTION OF IRON AND STEEL IN FEBRUARY.—The production of pig-iron in February amounted to 534,100 tons, compared with 574,500 in January and 612,700 tons in the corresponding month of last year. The number of furnaces in blast decreased by eight to 164 during February. The production of steel ingots and castings amounted to 646,400 tons compared with 767,600 tons in February, 1924.

BOROUGH POLYTECHNIC INSTITUTE.—The annual exhibition of work performed by students during the present session will be held on Saturday, March 28, from 6 to 9.30 p.m., at the Borough Polytechnic, Borough road, London, S.E.1. The engineering laboratories, in which machinery will be shown in operation, will be open for inspection. Demonstrations of testing, &c., will be given at intervals, while in the chemistry department experiments will be performed. A private view will be given from 3 to 5.30 p.m., tickets for which are issued by Principal J. W. Bispham.

# GEARED-TURBINE PADDLE TUG FOR THE RHINE.

*Fig. 1.*

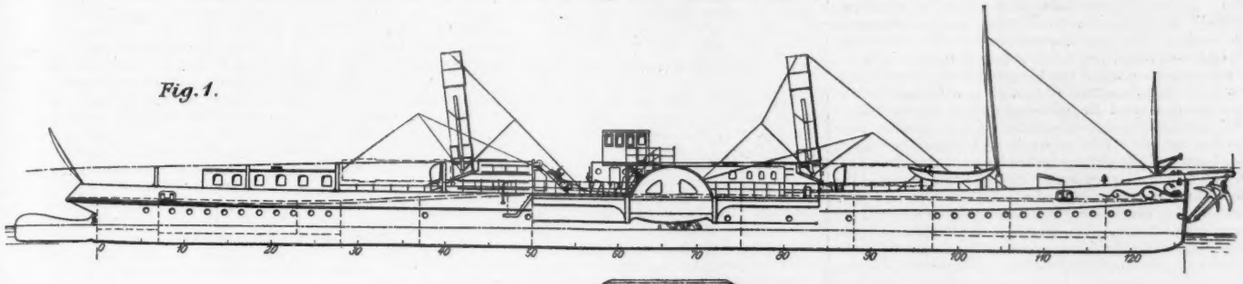
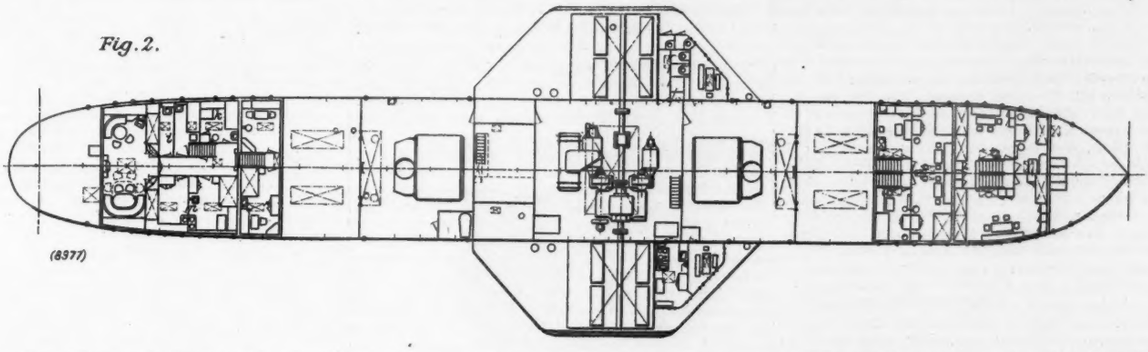


*Fig. 2.*



(8377)

## GEARED-TURBINE PADDLE TUG FOR THE RHINE.

THE chief interest of the Rhine steamer Dordrecht, which we illustrate in Figs. 1 and 2 above, lies in the fact that it is the first paddle-tug boat to be driven by geared turbines. Little, we think, has been done in the application of the steam turbine to the propulsion of river tugs even of the screw type, although a steam turbine was put into a small screw tug on the Rhine fifteen years ago, but it did not appear to offer any advantages. A small saving in coal is not one of the main factors for Rhine steamers, which take in coal almost directly from the collieries. For our information and illustrations in reference to the Dordrecht we are indebted to our contemporary, the *Zeitschrift des Vereines Deutscher Ingenieure*, of March 14.

The boat was built by the Schiffs-und Maschinenbau A.G., Mannheim, and was fitted with steam turbines by Messrs. Brown, Boveri and Co., of the same city. She has a length of 75 m. (246 ft.) between perpendiculars, a width of 9·5 m. (31¼ ft.) over frames, a maximum breadth of 22 m. (72 ft.) over the paddle boxes, and a draught of 1·19 m. (3 ft. 11 in.) fully equipped and with 10 tons of coal. With 150 tons of coal the draught is 1·43 m. (4 ft. 8 in.). The turbines are of 1,400 h.p. and the paddle wheels run at from 38 r.p.m. to 40 r.p.m.

The turbines work with steam at a pressure of 200 lb. per square inch and a temperature of 280 deg. C. (536 deg. F.). The gear ratio is 1 : 95. The tug was built for the service Mannheim-Rotterdam, but has at times to travel up to Basle. On that journey it has to pass under the Rhine bridge at Kehl, and the maximum height of the boat above the water-level had to be restricted to 4·68 m. (15⅓ ft.). The wheel house on the bridge and the bridge railing can, therefore, be tilted into the horizontal position, while the funnels are lowered in the usual way. The engines consist of a high-pressure and a low-pressure turbine, the latter embodying the astern turbine. Both the turbines run at 3,600 r.p.m., double-reduction gearing reducing the speed in two steps to 330 r.p.m., and then to 38 r.p.m. The gear wheels have helical teeth cut on a steel rim shrunk on a cast-iron cylinder. The lubrication oil pressure is 50 lb. per square inch. The main manœuvring valves are operated by a common hand wheel, and the turbines can be reversed within a few seconds. The two boilers are of standard marine type and were built by the M.A.N. Werk Gustavsburg.

The paddle wheels each weigh 43·3 tons. Each paddle is sub-divided in a vertical plane, the paddles of the inner and outer halves being staggered by half the paddle spacing; this arrangement has proved quite satisfactory. In the acceptance trials the tug pulled four boats of a total load of 6,287 tons in 16½ hours over the reach Duisburg-Cologne; this is nearly 1½ hours less than the period generally allowed for that journey under normal water conditions, although the river was in flood at the time of the trials. The coal consumption amounted to 1·3 lb. per shaft-horse-power hour, at 38·3 r.p.m., 1,575 h.p. being developed; the vacuum was 97 per cent. The draught was 1·40 m. (4 ft. 7 in.). The tug has proved quite equal to its work. Last summer the average performance of the engine was 1,650 h.p. at 39·5 r.p.m., according to Messrs. Brown, Boveri and Co. The coal consumption was decidedly less than is obtained with reciprocating engine tugs on the Rhine.

## THE LATE MR. G. F. BONNOR.

A FORMER chief electrical engineer of the Corporation of the City of Manchester, Mr. Gustavus Ferdinand Bonnor died in his 58th year, on Friday, March 6, at 4, Pembroke-villas, Richmond Green. He received his scientific training in the Wöhler Schule, Frankfurt-on-the-Main, and, after serving an apprenticeship from 1884 to 1889 in the works of Messrs. J. and H. Gwynne, Hammersmith Iron Works, London, he entered the service of the Metropolitan Electric Supply Company as a draughtsman to undertake the work connected with new stations within their area. On the completion of the stations he served as assistant engineer in two of them, and was then appointed station superintendent of the Whitehall station, where he remained until 1901. He then undertook the erection and maintenance of the power station for the Crystal Palace and District Electric Supply Company under Messrs. J. E. H. Gordon and Co. From here he proceeded to Bray Electricity Works in Ireland, where he was responsible for the erection of the plant and the laying of the cable system.

In 1893 he was appointed chief engineer and general manager to the Bath Electric Light Company, and on the purchase of the undertaking by the Corporation of Bath, Mr. Bonnor remained in charge and carried out many extensions to the system. He succeeded Mr. C. H. Wordingham as electrical engineer to Manchester Corporation, and on retiring in 1903 to enter private practice, his services were retained by that City to complete the extensions to Stuart-street station, which were then being made to his specifications. He was also consulting engineer to the corporations of Leigh, Salford, Winchester, and many other towns, as well as to private companies such as the Llandudno and Colwyn Bay Electric Traction Company.

In 1914, Mr. Bonnor, by deed poll, adopted the name he was later known by. It is very possible that many of those who took part in early power station development work may not be aware that his original name was Metzger, by which he will be long remembered and respected, especially by those who knew his work in Manchester.

THE INSTITUTION OF ENGINEERS, AUSTRALIA.—The address of the headquarters of the Institution of Engineers, Australia, until recently the Royal Society's House, 5, Elizabeth-street, Sydney, is now Macleay House, 16, College-street, Sydney, New South Wales.

## THE LATE MR. W. W. BRADFIELD.

FORMERLY electrical assistant to Senatore Marconi and later General Manager of the Marconi International Marine Communication Company, Limited, Mr. William Walter Bradfield contributed much to practical radio-telegraphy during his twenty-seven years of service in these capacities. To him, perhaps, more than to anyone else do the shipping community owe a debt of gratitude for the state of efficiency which has been attained in the maritime wireless service. His death in a London nursing home on Tuesday afternoon, March 17, at the age of forty-six years, will therefore be regretted by a much wider circle than that of his personal friends.

Mr. Bradfield was born in London, and received his technical education in the Finsbury Technical College. At the age of eighteen years, he was appointed electrical assistant to Senatore Marconi, and took part in the experimental work on Salisbury Plain. Later he assisted in the erection of the wireless station at the Needles, Isle of Wight. In 1899, Mr. Bradfield installed the first wireless apparatus on British battleships, and a little later took charge of the demonstrations to the United States Government on board the naval vessel Massachusetts. Similar service was rendered by him to the French Government in 1901, when communication was established between the French Riviera and Corsica. In the same year he supervised the erection of the stations at Siasconset, Nantucket Island, and on the Nantucket Lightship. The following year Mr. Bradfield became Chief Engineer to the Marconi Wireless Telegraph Company of America, and held this office until 1908, when he returned to England as deputy-manager of the parent company and of the Marconi International Marine Communication Company, Limited. He rendered great service to the International Radio-Telegraphic Conference in 1906. In 1910 he became manager of both Marconi's Wireless Telegraph Company, Limited, and the company concerned with marine wireless, and in 1917 was elected to the boards of directors of the two companies. Since 1920, Mr. Bradfield has devoted himself exclusively to the affairs of the Marconi International Marine Communication Company, Limited.

He was an associate-member of the Institution of Electrical Engineers and also of the American Institute, and a Fellow of the Institute of Radio Engineers of America. At the conclusion of the European War he received the C.B.E. for the services he rendered to the country in connection with wireless developments.

THE READING AND TESTING OF WATER GAUGES.—Attention had been drawn by the Board of Trade to the necessity for the exercise of proper care by engineer officers-in-charge when reading and testing water gauges if boiler explosions are to be avoided. Instruction in the proper tests to be applied to boiler water gauges is contained in the booklet "Regulations relating to the Examination of Engineers," which can be purchased from H.M. Stationery Office, price 6d. net.

## LABOUR NOTES.

AT the recent conference in Cologne, convened by the German metalworkers, and attended by representatives of the blastfurnacemen and steelworkers to consider "the present position of the eight-hour day in Germany and other Continental countries," Mr. J.T. Brownlie, secretary of the British Section of the International Metalworkers Federation, and president of the Amalgamated Engineering Union, stated that in Belgium, steel smelters and rolled-iron workers were paid at the rate of 38*s.* per week of 48 hours; in France, at the rate of 33*s.* per week of 48 hours, and in Germany, at the rate of 42*s.* 6*d.* per week of 60 hours, whereas the average weekly earnings of all British iron and steel workers in November, 1924, amounted to 63*s.* 7*d.* per week of 48 hours. The fact that the Germans worked longer hours and for lower wages militated, Mr. Brownlie went on to say, against the efforts of the British workers to obtain an advance of wages. British engineers had applied for a national advance of 20*s.* per week, and had been told by the employers that the increase could not be conceded owing to the severe competition from Germany and other Continental countries. It was imperative, Mr. Brownlie declared, that the German metalworkers should actively bestir themselves in order to secure the re-institution of the eight-hour day, higher wages, and improved working conditions; if they did not do so the adverse conditions prevailing in Germany would re-act to the detriment of the British metalworkers. In the event of the German metalworkers taking drastic action to "reconquer" the eight-hour day and obtain higher wages, they could depend, Mr. Brownlie said, on the support of the British trade union movement.

---

A resolution passed by the conference, and referring especially, apparently, to the hours and wages of blastfurnacemen, set forth that "in all European industrial countries, with the sole exception of Germany and Polish Upper Silesia," the three-shift day existed in the blast-furnace, steel and rolling works, the zinc, lead and copper works, and most departments of other industries. The conference, accordingly, appealed to all unions of blast-furnacemen and metalworkers in whose countries the eight-hours' day did not exist, to take all necessary measures with the object of securing the ratification of the Washington Agreement. "When changing from the double to the three-shift system," the resolution concluded, "not only a corresponding compensation of wages, but also an adequate increase will be necessary. In order to carry out these aims, the conference invites all concerned to join the organisations in their various countries which are affiliated to the International Metalworkers' Federation. The best guarantee for the re-introduction and security of the eight-hours' day in all countries is," it is added, "strong and capable syndicates, inspired with the spirit of fraternal co-operation."

---

The *Monthly Report* of the United Society of Boilermakers and Iron and Steel Shipbuilders, states that at the end of February 21,797 members were "signing the books" as compared with 21,213 a month earlier. The expenses for the month were 94,353*l.* 2*s.* 1*d.*; in January they were 103,840*l.* 18*s.* 4*d.*

---

The writer of an editorial note in the *A.E.U. Monthly Journal* claims that the engineering unions had a right to expect that the application made by them for an increase of wages would be dealt with on its merits with no side issue introduced. If the employers feel, he says, that they have a grievance respecting existing agreements there is nothing to prevent them raising such questions at any time after a settlement of the wages claim has been arrived at. There can be no doubt, whatever, it is argued, that there is an improvement in the engineering industry as compared with twelve months ago, and overtime is being worked in many shops. If, as seems to be probable, the unions are to wait until every firm connected with the Employers' Federation can be proved to be full up with orders, it is not unfair to suggest, the writer says, that to continue the process of making application for advances of wages on a national basis will adversely affect the interests of members, and a return to local or district applications will be insisted upon.

The substitution of local or district for national negotiations would, of course, carry matters no further forward, as under the provisions for avoiding disputes on failure to agree locally the difference would become the subject of consideration centrally. Not very long ago, more than one district—Manchester was one—took the course suggested, but the movements, no doubt for the reasons stated, were not persisted in.

---

The Ministry of Labour states that on March 9, 1925, the number of unemployed persons on the registers of Employment Exchanges in Great Britain was 1,220,700—936,500 men, 33,500 boys, 219,800 women, and 30,900 girls. On March 2, 1925, the number was 1,235,618—948,938 men, 34,390 boys, 220,759 women, and 31,531 girls—and on March 10, 1924, it was 1,113,825—822,720 men, 34,410 boys, 222,583 women and 34,112 girls. The figure of 1,235,618 for March 2 is 2,082 less than the provisional figure of 1,237,700 published a week ago for that date, the discrepancy being due to a large decrease shown in certain of the detailed returns which were received late. There was thus a decrease of 447 on March 2 as compared with February 23 instead of an increase of 1,635 as previously announced.

---

The Court of Inquiry set up by the Minister of Labour under Part II of the Industrial Courts Act "to inquire into and report upon the causes and circumstances of threatened disputes" in connection with the erection of steel houses, sat for the first time yesterday. It is composed of Lord Bradbury, Mr. C. T. Cramp and Mr. D. Milne Watson, with Mr. G. H. Ince as Secretary.

---

The Prime Minister's suggestion that the calling of a national conference is unlikely to serve any useful purpose until employers and employees in the principal groups of trade have reached some measure of agreement as to the best means of ensuring peace and co-operation in industry is generally regarded as wise. A considerable number of the people who are in closest touch with industry, unmistakably, however, incline to the belief that a national conference would serve no useful purpose at all and ought not, therefore, to be called. They draw that conclusion from the failure of the last joint meeting of the kind which was largely a fiasco, it will be remembered, because one or two important trade unions formally withdrew, and the representatives of others who remained had no authority to commit their organisations to anything. Obviously, if there is to be peace and co-operation in British industry, British industry itself—the trade unions and the organisations of employers, that is—must bring the much desired change about unaided by outsiders, however well-meaning, and encouraged by a well-informed public opinion. The meeting of the Mining Association and the Miners' Federation to consider the state of the coal industry is a promising step in the right direction, and the negotiations which are proceeding between leaders of the Shipbuilding Employers' Federation and the Engineering and Shipbuilding Trades Federation is another. It is a pity that the engineering trade unions have, so far, ignored Sir Allan Smith's appeal for a joint conference to consider how the economic position of their industry might be sufficiently improved to justify some increase of wages, for in the course of such an investigation a solution of engineering's present trouble might possibly be found. It is to be hoped that the rejection of the proposal by the men is not final, and that the examples of the miners, shipyard workers and the engineers will be followed by other groups. British industry's troubles are curable only by British industry itself, and the sooner that basic fact of the matter is recognised the better will it be for us all.

---

The *Ministry of Labour Gazette* states that among the 11,500,000 workpeople insured against unemployment under the Unemployment Insurance Acts in Great Britain and Northern Ireland the percentage unemployed at February 23, 1925, was 11·6, compared with 11·5 at January 26, 1925, and 10·7 at February 25, 1924. Among the members of those trades unions from which returns were received the percentage unemployed was 9·4 at the end of February, 1925, compared with 9·0 at the end of January, 1925, and with 8·1 at the end of February, 1924. The total number of persons registered at the Employment Exchanges in Great Britain and Northern Ireland as unemployed at February 23, 1925, was approximately 1,287,000, of whom 980,000 were men and 239,000 were women, the remainder being boys and girls; at January 26, 1925, it was also 1,287,000, of which 969,000 were men and 243,000 were women; and at February 25, 1924, it was 1,192,000, of which men numbered 878,000 and women 241,000. Employment was good on the whole with skilled operatives (other than painters) in the building trades, in some branches of the cotton industry, and in the brick and jute trades; it was fairly good with coachbuilders and mill sawyers and in the furnishing, silk, and carpet trades. In coalmining, in the wool textile industry, and in the section of the cotton industry spinning American cotton it was slack; in the iron and steel industry, in tinplate manufacture, and in the marine engineering and shipbuilding trades it continued bad.

---

In the industries for which statistics are regularly compiled by the Ministry of Labour the changes in rates of wages reported in February resulted in an aggregate reduction of 22,500*l.* in the weekly full-time wages of nearly 580,000 workpeople and an aggregate increase of 8,500*l.* in the weekly wages of over 90,000 workpeople. These statistics, however, are exclusive of changes in the rates of wages of agricultural labourers, a considerable number of whom obtained increases in wages in February as the result of orders issued by the Agricultural Wages Board. The principal groups of workpeople whose wages were reduced were coalminers in Yorkshire and the East Midlands, where the percentage addition to basis rates was reduced by the equivalent of about 1¼ per cent. on current rates, and steel smelters and millmen in various districts in England and Scotland, who sustained a reduction of about 1¾ per cent. on current rates. Other important groups of workpeople whose wages were reduced included coalminers in the Radstock district, cokemen and by-product workers in various districts, steel sheet millmen and galvanisers, Siemens steel workers in South-west Wales, blastfurnace workers in Cumberland, Lincolnshire, and Scotland, iron puddlers and millmen in Scotland, the majority of tinplate workers in South Wales and Monmouthshire, and workpeople employed in the dyeing and drycleaning industry.

---

Among those classes of workpeople who received increases in rates of wages in February were, the *Gazette* goes on to say, agricultural labourers in a number of counties, coopers in most of the principal towns, furniture trade operatives in London and Manchester, workpeople employed in the textile bleaching, dyeing, &c., industry in Scotland, road transport workers in Scotland, and employees of various local authorities in Yorkshire and London. During the first two months of 1925 the changes reported to the Department in the industries for which statistics have been compiled have resulted in net increases equivalent to over 50,000*l.* in the weekly full-time wages of 650,000 workpeople, and in net reductions of over 20,000*l.* in those of nearly 600,000 workpeople. In the corresponding period of 1924 there were net increases of nearly 180,000*l.* in the weekly full-time wages of over 1,600,000 workpeople and net reductions of 28,500*l.* in those of 580,000 workpeople. The number of trade disputes involving stoppages of work reported to the Department as beginning in February was 44. In addition, 20 disputes which began before February were still in progress at the beginning of the month. The number of workpeople involved in all disputes in February (including workpeople thrown out of work at the establishments where the disputes occurred, but not themselves parties to the disputes) was about 13,000. The estimated aggregate duration of all disputes during February was about 85,000 working days. These figures compare with totals of approximately 12,000 workpeople involved and 67,000 days lost in the previous month.

---

Although the scheme which the railway companies have suggested for overcoming the "shopmen" difficulty looks workable, a good deal will depend on the attitude which the craft unions take up towards it It has as its object, it is declared, "to afford full facilities for the discussion and settlement of all questions relating to the rates of pay, hours of duty, and general conditions of employment (other than matters of management and discipline)" of the adult male wages staff "employed under shop conditions." There will be direct application from the employees concerned to the management of the company in all matters other than those of a national character; the establishment of (*a*) shop and workshop committees and (*b*) departmental line committees where there are no shop committees, consisting of nominees of the company and elected representatives of the employees to deal with questions referred to them; direct negotiations between the headquarters of the trade unions and the company general manager on matters which cannot be settled between the staff concerned and the head of the department or his representative; negotiations between the Railway Staff Conference and the trade unions on questions of a national character; and if the parties fail to agree, but are prepared to submit the matter in dispute to arbitration, the matter will be referred to the Industrial Court.

---

The Shipbuilding Employers Federation have invited all the unions with members employed in the industry to send representatives to a joint conference to discuss the recent placing of orders by British shipowners in Germany and other foreign countries. The meeting is expected to take place in London next week.

---

THE INSTITUTION OF ELECTRICAL ENGINEERS.—The Faraday Medal which has been awarded by the Institution of Electrical Engineers to Sir J. J. Thomson, was presented to him at the ordinary meeting of the Institution on Thursday last.

# CUTTING TOOLS RESEARCH COMMITTEE.

## REPORT ON THE ACTION OF CUTTING TOOLS.*

By PROFESSOR E. G. COKER, D.Sc., F.R.S.

IN an earlier paper† the action of lathe tools was examined optically and some facts described which are possibly applicable to similar tools used in other kinds of machines for cutting and shaping metals. It seemed desirable, however, to examine at first hand other types of so-called cutting action, and a machine was constructed, therefore, which could be used as a planing machine or as a milling machine for transparent sheets of material. These latter must be so disposed that a polarised beam of light can be transmitted through them, and the stresses produced by the tools on the work measured by observations of the colour bands. It will be convenient here to describe the essential features of the machine devised for the double purpose of planing and milling operations on optical materials by reference to Fig. 1 (*a*) which shows a side elevation of the machine arranged for milling a plate A. A stout baseplate B of cast-iron is provided on which is mounted a slide-rest C, the movable head D of which carries suitable clamps to secure rigidly in position the transparent plate which

*Fig.1a.* MACHINE ARRANGED FOR MILLING

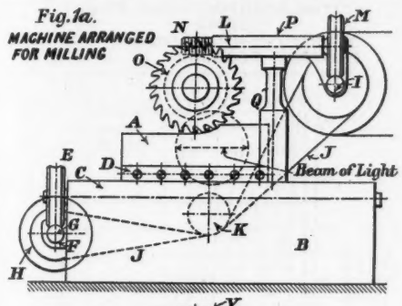
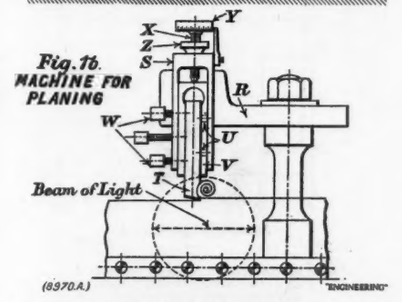



*Fig.1b.* MACHINE FOR PLANING




is to be subjected to the action of the tool. A continuous feed is given to this plate by the operation of the slide-rest screw, which latter carries a worm wheel E driven by a worm F integral with the shaft G. A stepped pulley H secured on the other end of the shaft is connected to the main driving shaft I by a belt J carried over a pair of guide pulleys K, which latter are capable of some adjustment to prevent slip of the belt. In practice this arrangement is found to give a very uniform feed, as the forces acting are comparatively small and the extra complication of a train of wheels to give a positive feed is not necessary.

It is convenient in many cases to have the opportunity of quickly bringing back the work to the initial position required to start a cut without using the comparatively slow feed motion employed while cutting action is taking place, and to this end the worm shaft G is carried in bearings which permit the whole shaft to turn about a line intersecting its axis at right angles when required. This movement throws the worm F out of gear, and the slide-rest screw can then be turned by hand until the plate is in position and ready for a new cut. The shaft G is then put into gear again and locked in place by a set-screw.

For milling it is necessary to provide means for turning the cutter at a definite rate with reference to the feed motion, and for this purpose the first motion shaft I drives a second shaft L by a worm gear M, and the milling cutter is turned round by a second similar worm gear, of which only the worm N is visible in Fig. 1, and the worm wheel O is hidden by the cutter and is indicated by a dotted circle. The modifications required when this machine is used as a planer are easily made, since in this latter case the tool is fixed and the double worm gear is not required. These alterations are shown in Fig. 1 (*b*). All that is necessary is to replace the plate P secured to the standards Q by a new plate R, carrying a driving pulley for actuating the feed and also the tool-holder S. The tool T in this arrangement is securely gripped by two set-screws U in a bar V of rectangular cross-section, sliding in a corresponding holder S, and secured in position by three set-screws W. The depth of cut is regulated by a screw X provided with a graduated head Y and a lock-nut Z. This arrangement allows the tool to be reversed at the end of a traverse and readjusted for a new cut without the necessity of returning the plate to its original position. It is, in fact, used for cutting in either direction.

*Planing Tools.*—It will be convenient to begin by describing the action of a planing tool when operating on nitro-cellulose, and the accompanying Fig. 2, drawn from a photograph, shows the general features observed. As in a turning tool, we have almost exactly the same kind of colour bands springing from or near the point of the tool, while the shavings produced present no essential feature of difference. If the tool has a perfectly made cutting edge and the angles are suitable, the shaving shows the brilliant colour effects of over-stress, although at the zone of separation it is impossible to see through it owing to

*Fig.2.* PLANING TOOL OPERATING ON A STRIP OF NITRO-CELLULOSE IN POLARIZED LIGHT.

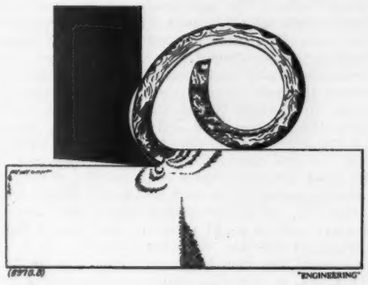
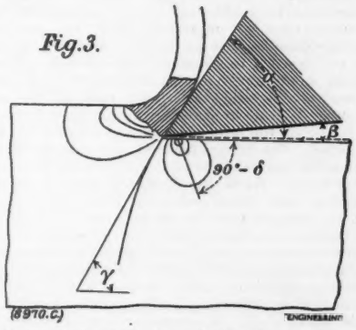



*Fig.3.*




the black patch which is stationary in position and in front of the cutting edge.

A complete analysis of the stress distribution shows scarcely any differences from those already found with lathe-tools, except that the minor principal stresses are somewhat less in magnitude. One or two matters of interest refer to the angular position of the black brush dividing the area under approximately radial tension from that in approximately radial compression when the tool angles are varied. Table I shows some

TABLE I.

Observations of the angular position of the black brush near the cutting edge of a planing tool. Thickness of nitro-cellulose 0·188 in. Depth of cut measured by feed screw 0·02 in.

| Tool Angles. | | Inclination of Black Brush | Inclination of Line Perpendicular to Axis Tension Lobe. |
|---|---|---|---|
| Cutting Angle $\alpha$ | Clearance Angle $\beta$ | $\gamma$ | $\delta$ |
| deg. | deg. | deg. | deg. |
| 20 | 5 | 50 | 28 |
| 30 | 5 | 55 | 32 |
| 30 | 10 | 57 | 34 |
| 45 | 5 | 59 | 32 |
| 45 | 10 | 58 | 34 |
| 60 | 5 | 64 | 39 |
| 60 | 10 | 65 | 44 |
| 75 | 5 | 74 | 68 |
| 75 | 10 | 81 | 78 |
| 90 | 5 | 86 | 86 |
| 90 | 10 | 86 | 86 |

results obtained with a cut 0·02 in. in depth used on nitro-cellulose of 0·188 in. thickness, and as will be seen from Fig. 3, the angles $\alpha$ and $\gamma$ are widely different for small values of the former and tend to equality when $\alpha$ is large. In a similar manner a considerable difference is found between the angles $\gamma$ and $\delta$ for small values of $\alpha$ and again tending towards equality when $\alpha$ is large. There is some difficulty in measuring the angles $\gamma$ and $\delta$ with accuracy, but the general trend of the values is probably sufficiently indicated by these measurements. This data affords a clue to the general direction of the force exerted by the point of the tool on the work, but, as appears later, it is complicated by stresses due to an uplift effect.

An interesting phenomenon, first noticed in connection with a planing tool, is that after a cut has been made and the tool run back, it is sometimes found that the point of the tool is not in contact with the work. This is particularly noticeable when the tool angles are such that the surface is left somewhat rough. In some cases the same effect has been observed in a metal. The order of magnitude of the quantities observed may be indicated by an experiment on a plate of nitro-cellulose under a cut of 0·04 in. applied by a tool with a cutting angle of 30 deg. and clearance angle of 5 deg. The cut surface was found to be 0·004 in. below the point of the tool, of which amount 0·001 in. was traced to bending of the tool itself and 0·001 in. was due to spring in the shaper. Hence the drop of the surface not accounted for was 0·002 in., so that the material must have been pulled up this amount by the action of the tool. The amount of this distortion diminished regularly in the vertical line below the point of the tool and was found to be 0·00075 in. at a distance of $\frac{1}{16}$ in. away. In the case of a metal an example may be cited of a $\frac{1}{16}$ in. brass plate subjected to a cut of 0·015 in. in a Lang lathe by a tool with angles $\alpha = 45$ deg. $\beta = 3$ deg. The surface lift in this case was 0·003 in. and a line 0·008 in. below the cut surface was lifted 0·001 in., while a similar line 0·024 in. below was lifted 0·0005 in.

It seems possible from these experiments that rough surfaces on materials may be due to this local distortion from the tearing action produced by this uplift whenever it occurs. It is also probable that the distortion of the colour bands from the circular form, as indicated in the upper part of Fig. 3, may be explained by this especially when it is noticed that the lower tension lobes approximate much more nearly to circles. In the case of a mild-steel plate, for example, when a shaving of $\frac{1}{100}$ in. thickness is being removed with a tool of cutting angle of 60 deg. and a rake of 3 deg., the distorted area has a boundary of the form shown by the curve CDE of Fig. 6, with a horizontal range of about 0·05 in. and a vertical range of 0·02 in., and there is also some trace of overstress in the upper part of the boundary line EF due to a previous cut, and similarly in the lower boundary CG due to the present one. There is no trace, however, of a boundary corresponding to the colour bands behind a tool when cutting transparent material and due to the tensional pull exerted on the material, and it might, therefore, seem that this "bow wave," advancing with the tool as it cuts into the material, is merely due to the small thickness of the plate and will therefore not appear if a thicker plate is employed, but this latter view is not confirmed by experiment. The extent of the region bounded by this zone naturally varies very much with both the tool and the physical characteristics of the steel.

The permanent distortion of the material appears to be confined to the upper region A, bounded by the zone CDE, and this may be accompanied by elastic strains in the material outside this region, which cause horizontal lines to assume a curved form culminating in a peak under the point of the tool, sometimes directed upwards, more especially in tools with small cutting angles, or downwards, as often happens, with tools having large cutting angles, such as are sometimes used for cast iron. If in any part of the zone CDE lies below the line GC, then the cut surface will receive some permanent overstress and overstrain. If, however, such a condition is found that no part of the zone is below the newly-cut face, then there cannot be any permanent distortion. This latter condition also seems in general to be associated with the absence of permanent distortion of horizontal lines below the tool, for then this latter is neither exerting a force tending to tear the shaving away from the main body, or to force it into the material. Both actions of this latter type cause rough surfaces, necessarily of less accuracy than those produced by tools which neither tear up a shaving or try to push it into the material. It would appear from this that tools which are so shaped as to fulfil these latter conditions are, in general, also the most economical in action, since the work done is a minimum, and wherever possible it seems that the correct objective of all light cutting operations of the nature of planing and turning should be such as to produce the desirable features indicated above.

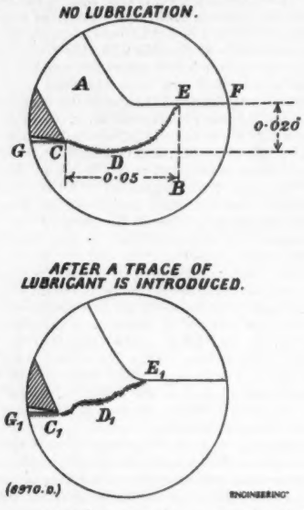
*The Effect of Lubrication.*—An examination of the cutting action of tools operating on mild steel shows that the zone of demarcation described above is

* Presented at the meeting of the Institution of Mechanical Engineers, Friday, March 13, 1925. Abridged.

† See ENGINEERING, vol. cxiii, page 564.

greatly influenced by a lubricant. For example, the smallest trace of oil causes an immediate contraction of the curve C D E, Fig. 6, to a new position $C_1$ $D_1$ $E_1$ indicated in the diagram below. This change is visible under examination with a low-power microscope, is immediate, and persists even with a trace of lubricant. In order to revert to the dry conditions described with reference to Fig. 2, it has often been necessary to remove the lubricant by chemical

*Fig. 6. BOW WAVE IN A MILD STEEL PLATE. ANGLE OF CUTTING TOOL-60°; RAKE-3°.*




means, as mechanical operations were found insufficient. The new line C D E in steel is almost invariably above the line C G of the cut. The ease with which a smooth surface is produced under lubricated conditions is evidently associated with the position of this boundary, while the contraction of the area under permanent distortion, instant by instant, shows that the work required to effect the cutting operation in this material is less than in the dry condition.

*(To be continued.)*

---

## EXPERIMENTS WITH LATHE TOOLS ON FINE CUTS, AND SOME PHYSICAL PROPERTIES OF THE TOOL STEELS AND METAL OPERATED UPON.

By DEMPSTER SMITH, M.B.E., M.Sc.Tech., and ARTHUR LEIGH, M.Sc.Tech.

A LARGE number of investigations have been made with metal cutting tools in order to determine how the durability of the tool was affected by changes in the depth of cut, traverse, cutting speed, cutting angle, section of the tool steel, contour of the cutting edge, and the material operated upon. In the main these tests have been made with single cutting edged tools of the lathe type on comparatively coarse cuts, and were undertaken in order to find the most economical cutting speeds for use in the workshops. The wide range of cutting speeds obtainable with modern high-speed steels in comparison with that of the old carbon-steel has rendered necessary these inquiries.

Whilst the speed-durability curves for heavy cuts show that the durability decreases continuously as the speed increases, it has been shown by Mr. E. G. Herbert that for light cuts the durability increases with the speed up to a maximum, declines and increases again to a second maximum, and finally falls off at higher speeds.

*Measure of Durability.*—Results have been advanced to show that the vertical force of a compact shaving of a given depth of cut and traverse remains practically constant at all speeds, and consequently it was thought that a certain percentage increase of the initial force would afford a suitable measure of durability. For the purpose of measuring the vertical force while cutting progressed, a dynamometer of the design described later in the paper was used. This was fitted to the turret of an ordinary No. 4 Herbert Combination Lathe.

With such extremely light cuts it was found that the force for a given cut did not remain quite constant at all speeds, but by adopting a percentage increase of the initial force, this small variation did not appreciably affect the standard. A number of preliminary experiments were carried out to ascertain the percentage increase which would give the best measure of performance. The curves shown in Fig. 1 give the time required to attain a percentage increase of the initial vertical force of 5, 10 and 15 respectively. With a 15 per cent. increase the cutting edge of the tool was seriously injured, whilst with a 5 per cent. increase the cutting edge was not impaired. A 10 per cent. increase corresponded with the stage at which the operator sought to withdraw the tool for regrinding, and was taken as the measure of durability. This 10 per cent. increase in the initial vertical force approximately corresponded to a 15/10,000 in. wear of the cutting edge and bore a distinct relation to the breakdown point of the tool.

The experiments were made with the object of obtaining the characteristic durability-speed curves for carbon and high-speed steel tools, and with the object of linking together the results obtained with coarse and extremely fine cuts.

The carbon tool-steel used was supplied by Messrs. Hadfield, Limited, and had the following percentage composition: Carbon, 1·28, manganese 0·28, silicon 0·10, nickel 0·065, phosphorus 0·018, sulphur 0·005.

The high-speed tool-steel used was an ordinary A.W. high-speed steel having a composition as follows: carbon 0·65, tungsten 13·08, chromium 2·97, vanadium 0·52.

The metal used in the tests was a medium steel having a tensile of 41·6 tons per square inch, and a composition as follows: carbon 0·35, silicon 0·15, magnanese 0·14, sulphur 0·06, phosphorus 0·04.

In order to ascertain what changes took place in the hardness of the various steels used with increase in temperature, a number of tests were carried out on specimens of the steels with the Herbert Pendulum Hardness Tester. The heat treatments to which these specimens were subjected were identical to those given to the tools. The medium steel specimen, of course, received no heat treatment.

It was seen that with the carbon steel hardened only specimen, the hardness diminishes as the temperature increases up to about 70 deg. C., but increases rapidly between this temperature and 125 deg. C., beyond which temperature a consistent diminution in hardness occurs. In the case of the tempered specimen the initial drop in the hardness is practically eliminated, the steel showing a distinct hardening up to about 120 deg. C. At higher temperatures the hardness falls away with a slight check in the rate of fall in the region of 275 deg. C.

Examining the time-hardness curves for the high-speed steels, it was seen that after hardening at a temperature of 1,320 deg. C. any subsequent heat treatment does not materially affect the pendulum time-hardness readings for temperatures ranging from cold (15 deg. C.) to about 60 deg. C., each specimen showing a tendency to harden as the latter temperature is reached. Beyond this point each of the steel specimens appears to have peculiar hardness properties depending on the heat treatment to which it has been subjected. The general tendency of the hardened only steel is for the hardness to decrease with increase in temperature. When the hardened steel is given a secondary heat treatment at a temperature of 450 deg. C., the first point at which a minimum value in the hardness readings occurs is moved slightly towards the lower temperatures, but the second minimum point is practically removed altogether, the hardness readings remaining equal in value to that when cold from 220 deg. C. to 400 deg. C., after which a rapid fall is again established. A secondary heat treatment at 575 deg. C. moves the point of minimum hardness still further to lower temperature, and at the same time lengthens the period through which the hardness values remain steady up to a temperature of about 460 deg. C. in addition to bodily lifting the curve. For the specimen heat treated at 575 deg. C. the irregularities of the hardness are not so marked as for the hardened only specimen, and the steel attains a hardness at 475 deg. C. equal to that when cold. When this steel which has received a secondary heat treatment at 575 deg. C. is given a further treatment at a temperature of 450 deg. C., the point at which the minimum value occurs is about the same temperature as in the preceding case, but the holding up of the hardness readings is found to be discontinued at a temperature of about 350 deg. C.

The results of time-hardness tests carried out on specimens of the medium steel used in the cutting trials show that the hardness decreases slightly from cold to about 100 deg. C., after which it increases until, at a temperature of 300 deg. C., the hardness is above that when cold. From 300 deg. C. to 430 deg. C. the hardness remains fairly constant, but above the latter temperature it falls off rapidly. Whilst not seeking to advance a claim that the hardness indications of tool steel at different temperatures here presented, give a measure of the cutting capabilities of the steel, yet, from the marked similarity between the character of the hardness curves and that of the durability curves obtained with cutting tools on extremely light cuts, it would appear probable that the hardness indications of the tool steel and of the material operated upon may afford a clue to the durability peculiarities met with in cutting.

All the tools were of rectangular section, 1 in. deep by ¾ in. wide, and similar in form to a knifing tool. They were ground to a side cutting angle of 60 deg. or side top rake of 30 deg. (no front top rake), front and side clearances of 1½ deg., and a front top clearance of 3 deg. with no nose radius. When in use the cutting edge of the tool was in a horizontal plane in line with, and at right angles to, the axis of the test bar. The results of experiments with single-edged cutting tools

*Fig. 1. TIME FOR PERCENTAGE INCREASE OF THE VERTICAL FORCE AT DIFFERENT SPEEDS*

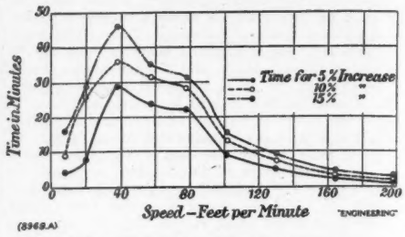



*Fig. 5. VARIATION IN DURABILITY WITH CUTTING SPEED FOR CARBON-STEEL TOOLS*
*DEPTH OF CUT-0·0625 INCH*
*TRAVERSE-0·0013 INCH*

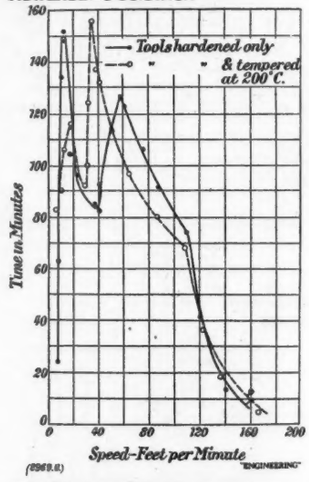
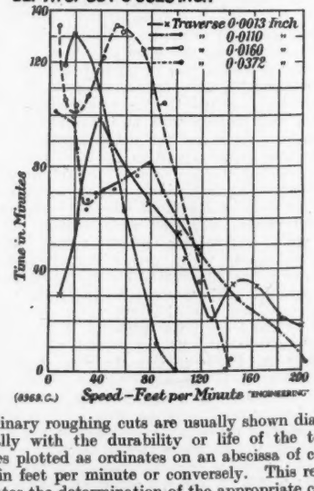



*Fig. 6. VARIATION IN DURABILITY WITH CUTTING SPEED WHEN OPERATING WITH VARYING TRAVERSES*
*HIGH-SPEED TOOLS-HARDENED AT 1320° C & HEAT TREATED AT 575° C. CONSTANT DEPTH OF CUT 0·0625 INCH*




on ordinary roughing cuts are usually shown diagrammatically with the durability or life of the tool in minutes plotted as ordinates on an abscissa of cutting speed in feet per minute or conversely. This relation facilitates the determination of the appropriate cutting speed for the most economical life of tool when operating on different materials or with different tool steels. In determining the economical speed, one has to compare the gain due to the increased speed of cutting with the complete costs involved in removing and replacing the spent tool.

The durabilities of the carbon-steel tools when

operating with a very fine cut of 0·0625 in. deep and 0·0013 in. traverse, are shown plotted against cutting speed in Fig. 5. The general character of the curves is similar to that obtained when operating with high-speed steel tools on medium steel with the same cut.* An examination of the results show that the hardened only tool has points of maximum durability at 10 ft. and 60 ft. per minute, while a tempering treatment causes the corresponding peaks to approach each other and occur at 20 ft. and 35 ft. per minute respectively. If the hardness of the medium steel be a measure of the resistance to cutting, and that of the tool steel a measure of the resistance to abrasion, then, if these be the principal factors affecting durability, the ratio of the two should give a curve corresponding to the durability speed curve when the temperatures appropriate to the cutting speeds have been determined. A curve so constructed, however, only approximately agreed with those actually obtained, and it seems that some other effect, possibly vibration, which would injure the cutting edge of the tool or that the "work hardness" of the tool would need to be included before a definite relation could be established. The results are in agreement with the experience of observant machinists, who find that under certain conditions with such light cuts an increase in the cutting speed will result in an increased durability. A comparison between these and the results obtained with the high-speed steel tools, Fig. 8, shows that for speeds below 80 ft. per minute the average durabilities for the carbon steel are quite as good as those for the high-speed steel tools for the same dimensions of cut. It would therefore seem that for cutting tools such as files, hand reamers, taps, &c., used for light cuts and comparatively low cutting speeds, carbon steel would be the most economical material, since the initial and manufacturing costs of the tools are less.

One of the principal objects of this investigation was to study the performance of the tool as the cut was gradually increased from extremely small to something approaching ordinary roughing cuts. To do this it was decided to observe, first, the effect due to a variation in the traverse keeping the depth of cut constant, and, secondly, the effect due to a change in the depth of cut with a constant traverse. The results obtained with the increasing traverse, with tools which had received a secondary heat treatment at 575 deg. C., are shown diagrammatically in Fig. 6. From this it is seen that with a traverse of 0·0013 in. and within the speed limits of the trials, the greatest durability is obtained at 40 ft. per minute, above which speed the durability diminishes to 20 minutes at a speed of 130 ft. per minute. Beyond the latter the durability again increases to 35 minutes, forming a peak in the curve at a speed of 155 ft. per minute, and decreases beyond this. It is clear that the durability curves move bodily towards the lower speeds as the traverse is increased. This is due to the increase in the temperatures of the tool and shaving brought about by the increase in heat generated in removing the bigger dimensioned cuts. The hardness values for the tool and metal operated upon are much the same at the low speeds for the heavier cuts as those associated with higher speeds and finer cuts. The movement of the curves towards the left of the figure indicates that, when the traverse is increased to that of an ordinary roughing cut and taken at workshop speeds, the peaks will be completely eliminated and the regular durability-speed curves commonly associated with roughing cuts will be obtained.

The results obtained with increase in the depth of cut are shown in Fig. 7, from which it will be observed that the point of maximum durability with increase in the depth of cut occurs at the lower speed for the same reason as that attributed to the results of the increasing traverse. The material available was insufficient to permit of an extension of the series. It cannot be claimed that the time-hardness indications are an absolute measure of the life of the tool, since it is seen that while the secondary heat-treated tools have hardness values superior to those of the hardened only tool at all temperatures, the latter tool gives a much greater durability at the lower speeds. This is further emphasised if a comparison be made between the hardness values and the durabilities of the carbon-steel tools. It is possible that for each grade of steel and each heat treatment there is a specific hardness value corresponding to the durability, but this, of course, is of no practical value. The secondary heat-treated tools gave the greatest durability at high speeds, but at low speeds where the vibration was very small the effect of the "shortness" factor of the hardened only tool exceeded that of the "resistance to flow" factor of the secondary heat-treated tools and resulted in a greater durability. Even when the cut is increased to 0·0625 in. deep by 0·011 in. traverse the superiority of the hardened only tool is still maintained at the low speeds, although not to such a marked degree as with the finer traverses, Fig. 9. It is possible that the heat treatment may influence the "work hardness" of the tools.

The results when operating dry can be contrasted with those obtained when using a cooling medium on a cut of the same dimensions which are also shown in Fig. 9. Hitherto the variations in the durability-speed curves have been attributed to the changes in the hardness of the tool steel and the metal operated upon consequent upon temperature changes. If this assumption be correct, then the conditions obtaining when taking a medium cut and using a cooling agent should

* Trans., Manchester Association of Engineers, 1924.

**Fig. 7. VARIATION IN DURABILITY WITH CUTTING SPEED WHEN OPERATING WITH VARYING DEPTHS OF CUT.**

**HIGH-SPEED STEEL TOOLS—HARDENED 1,320° C., & HEAT TREATED 575° C. CONSTANT TRAVERSE 0·011-INCH.**

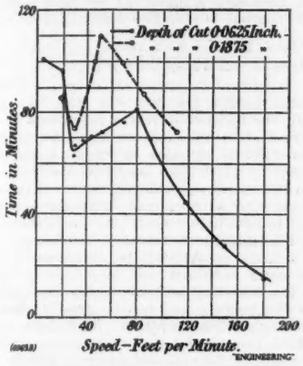
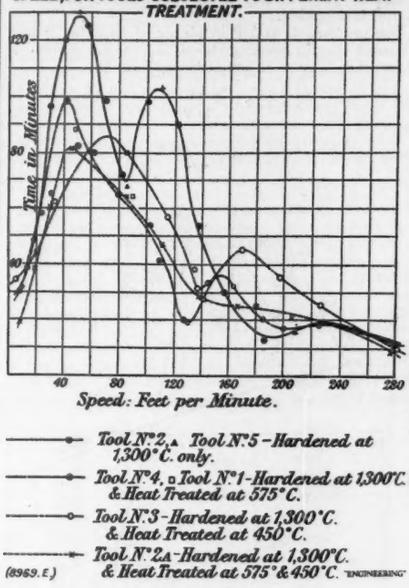



**Fig. 8. VARIATION OF DURABILITY WITH CUTTING SPEED, FOR TOOLS SUBJECTED TO DIFFERENT HEAT TREATMENT.**

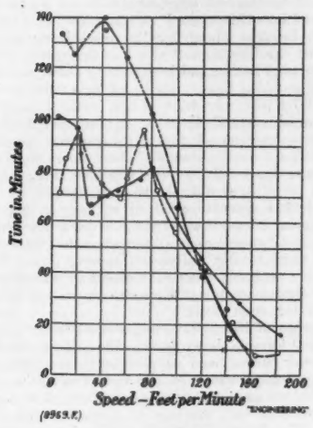



Tool N°2, ▲ Tool N°5—Hardened at 1,300° C. only.
Tool N°4, □ Tool N°1—Hardened at 1,300° C. & Heat Treated at 575° C.
Tool N°3—Hardened at 1,300° C. & Heat Treated at 450° C.
Tool N°2A—Hardened at 1,300° C. & Heat Treated at 575° & 450° C.
(8969. E.) ENGINEERING

**Fig. 9. VARIATION IN DURABILITY WITH CUTTING SPEED FOR HIGH-SPEED STEEL TOOLS**

**CUT—0·0625 INCH DEEP × 0·11 INCH TRAVERSE**

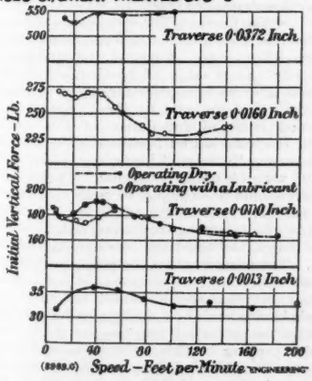
——•—— Hardened 1320° C. only. Operating Dry
——•—— " 1320° C. & Heat Treated 575° C., Operating Dry
– – –•– – – " 1320° C. & Heat Treated 575° C., Operating with a Lubricant




(8969. F.)

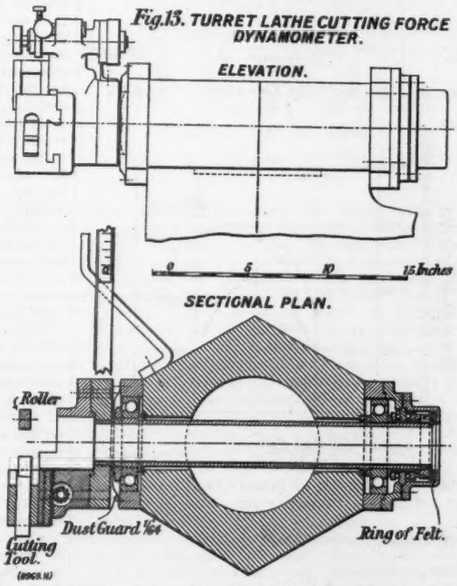
**Fig. 12. VARIATION OF VERTICAL FORCE WITH SPEED**

**HIGH-SPEED STEEL TOOLS—HARDENED 1320° C., & HEAT TREATED 575° C**



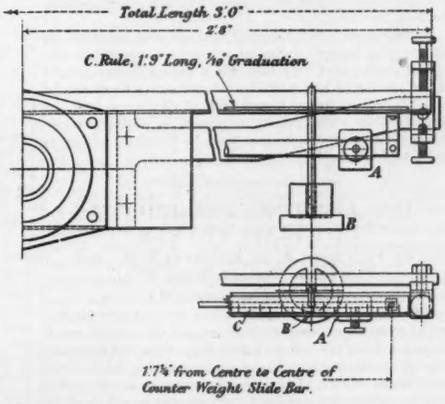

(8969. G.)

**Fig. 13. TURRET LATHE CUTTING FORCE DYNAMOMETER.**




(8968. H.)

**TURRET LATHE CUTTING FORCE DYNAMOMETER.**




A. Movable Weight to Balance Roller Turner Head
B. Adjustable Weight Moving on Scale C to Balance the Cutting Force.

(8968.)

approximate to those resulting from a light cut when operating dry. This is generally substantiated by the results shown in Fig. 9, where the complete double-peaked curve is again reproduced. The opinion is commonly held that at the higher speeds the durability of a tool is much greater when a cooling medium is used than when without. Contrary to this belief, however, it was found that beyond about 130 ft. per minute, the tool, when cooled by a cutting compound of lard, oil, and water, broke down after a comparatively short run and could not be made to attain the durability of the tool when operating dry. Water alone was substituted, but the results obtained were even worse and are shown by the dotted circles in Fig. 9. An examination of the failure of the tool when cutting without and with a cooling medium at a speed of 140 ft. per minute showed that in the first case a "build up" had formed on the tool edge, whilst in the second the tool showed no evidence of "building up" and failure had been brought about by the nose being rubbed away. An examination of the bar suggested that a severe plucking action had been taking place, and that the raised portions thus formed had been subsequently burnished by the front face of the tool.

The initial vertical force acting on the tool was measured by means of the dynamometer described below. The forces obtained when operating with a constant depth of cut (0·0625 in.) and varying traverses (0·0013, 0·011, 0·016 and 0·0372 in.) are shown plotted against speed of cutting in Fig. 12. The diagram shows that this force does not remain constant at all speeds as has been suggested by experimenters when taking ordinary roughing cuts. Their results were probably due to the use of an insufficiently sensitive dynamometer and also to the range of temperatures for such cuts.

The design of the dynamometer used for measuring the vertical force is shown in Fig. 13. The tool is held in the roller turner head supplied with the lathe, but instead of being carried by the turret face, the roller head is bolted to a cast-iron flange fastened to a steel tube fitted with ball bearings at opposite sides of the turret. The bearing furthest removed from the fast headstock of the machine is arranged to take the thrust acting parallel to the axis of the bar.

When taking a cut, the force on the tool tends to turn the arrangement about the longitudinal axis of the bar in a counter-clockwise direction when looking towards the headstock.

In the experiments the cutting force was balanced by means of a weight hung on a lever connected to the turner head. For very fine cuts a sliding jockey weight of 2 lb. was used, but with the heavier cuts a fixed weight was placed at the extreme end of the lever and the final balance obtained by means of a sliding weight. An independent weight was used to balance the turner head and the tool.

## THE LIMITING POSSIBILITIES IN STEAM PLANTS.*

By PROFESSOR A. L. MELLANBY D.Sc., and PROFESSOR WILLIAM KERR, Ph.D.

(*Concluded from page* 336.)

*The Limits of Reheating.*—We have, then, by two main lines of argument, determined the initial conditions of 1,250 lb./in² and 900 deg. F. as representing the probable limits. Any cycle starting from these conditions would be liable to variation of overall efficiency by changes in the range and number of the reheating and feed-heating operations. We may take these features separately; and, since the feed-heating conditions must, of necessity, be determined from the expansion lines fixed by the best reheating values, the reheating considerations should be taken first.

The problem here is comparatively direct. In an estimate of thermal efficiencies with different ranges and steps of reheating we require to introduce factors that will cover those effects resulting from reheating which may influence the net efficiency. Besides the thermodynamic gain due to the process, which is naturally incorporated in the mode of calculation, there is the improvement due to the smaller proportion of wet field expansion with increase of the reheating range. The rule of stage efficiency varying directly with dryness fraction applies here. If the total available heat is H, that part of it lying within the wet field $m$.H, and the final dryness fraction $q_o$, then the factor covering the wet field is:

$$\frac{m\,\mathrm{H}\left(\frac{1+q_o}{2}\right)+(1-m)\,\mathrm{H}}{\mathrm{H}} = 1-\frac{m}{2}(1-q_o) \quad (9a)$$

This factor, then, applies to any estimate of thermal efficiency that assumes no variation of stage efficiency with reheating range.

Again, if the search were only for the best condition with a single reheating stage, we should hardly require to consider the question of pipe losses; but when the number of stages, with consequent multiplication of piping systems is involved, it is necessary to realise that these losses will tell most heavily against the multiple system. Hence an estimate of this kind should be included.

The pressure drop Δ P in piping of diameter D and constant length, passing steam of specific volume V at speed $u$, is given in proportional form by

$$\Delta \mathrm{P} \propto \frac{u^2}{\mathrm{D\,V}}$$

but

$$\mathrm{D} \propto \sqrt{\frac{\mathrm{M\,V}}{u}}$$

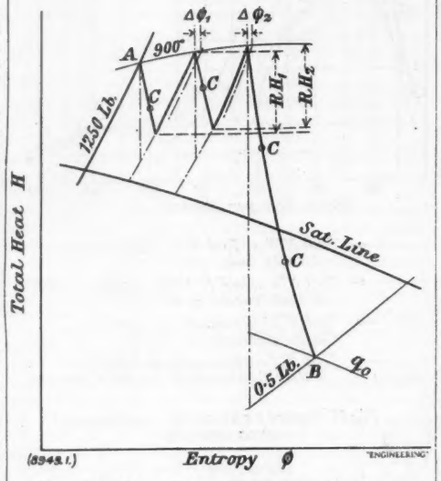



FIG. 9. MULTI-STAGE REHEATING CYCLE ON H — φ CHART.

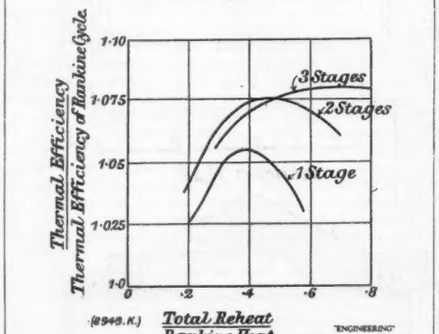



FIG. 10. EFFECT OF RANGE AND STAGES IN REHEATING.

and therefore with M constant

$$\Delta \mathrm{P} \propto \sqrt{\frac{u^5}{\mathrm{V^3}}}$$

Hence

$$\frac{\Delta \mathrm{P}}{\mathrm{P}} \propto \sqrt{\frac{u^5}{\mathrm{V}}} \quad . \quad . \quad . \quad (10)$$

if we allow that P.V. is constant.

If this ratio were kept constant, the pressure drop in the pipe would have practically no influence on the change of efficiency with variation of the reheating range. It must, of course, be considered on account of the changing number of steps, but the constancy of the ratio Δ P/P is obviously a very suitable condition to apply to the piping system. Accepting it, we have that

$$u \propto \mathrm{V}^{\frac{1}{5}}$$

and hence the variation of pipe size is given by

$$\mathrm{D} \propto \mathrm{V}^{\frac{2}{5}}.$$

Now the heat loss from the pipe may be held to depend on the diameter, and hence will also vary as $\mathrm{V}^{\frac{2}{5}}$ or, as we may put it, $\mathrm{I/P}^{\frac{2}{5}}$.

Since we have the order of variation of pressure and heat losses if is only necessary to choose standard values for these in order to include their influence in the consideration of efficiency variations. The values chosen are

$$\frac{\Delta \mathrm{P}}{\mathrm{P}} = 0{\cdot}025, \text{ and}$$

heat loss = 10 B.Th.U. per lb. of steam.

which latter is held to apply at a pressure of 100 lb.

The complete procedure may readily be followed from the sketch, Fig. 9. For any assumption regarding extent and stages of reheating the expansion lines are fixed through the constant stage efficiency and the reheat factors. This gives the point B, Fig. 9. The reheating is taken as carried up to 900 deg. F. at each step. The dryness fraction at B gives $q_o$, and the ratio $m$, giving the available heat in the wet field, is easily derived. The appropriate value of Δ P gives an entropy value Δ $\phi$ at each reheating point, so that the effect of pressure loss can be considered simply as a growth of entropy. The heat loss in the piping is readily obtained from

$$\Delta h = \frac{10}{(\mathrm{P}/100)^{\frac{2}{5}}} = \frac{63}{\mathrm{P}^{\frac{2}{5}}} \quad . \quad . \quad (11)$$

where P is the reheating pressure.

The wet-field loss is then included by means of the factor already given. The pipe-pressure effect shows itself as a loss of available heat, while the heat loss represents a necessary addition to the heat supply. The thermal efficiency is therefore determined from

$$\epsilon = \left\{\frac{\mathrm{H_A - H_B + \Sigma\,R\,H - T_B\,\Sigma\,\Delta\,\phi}}{\mathrm{H_A - h_b + \Sigma\,R\,H + \Sigma\,\Delta\,h}}\right\}\left\{1-\frac{m}{2}(1-q_o)\right\} \quad (12)$$

The essential results are shown in Fig. 10. The non-reheating—or Rankine—cycle is taken as a basis, and the curves show the improvements above this basis due to different amounts of reheating and the number of steps by which these amounts are added. It is clear that two stages are definitely better than one, and that three offer a very small additional benefit; but, in order to obtain this small gain, a considerable increase in the amount of reheat is necessary. On the other hand, the relatively large advantage of two stages over one is obtained with only a very slight increase in the reheating amount, hence the heating elements in the boiler would not be greatly affected by the doubling of the operation. It follows quite definitely that two stages of reheating requiring a total heat supply of between 40 per cent. and 50 per cent. of the Rankine heat drop provide the true limit to the reheating process. This condition is closely met by reheating pressures of 500 lb. and 180 lb./in², and we may accept the cycle so defined as the net result of our investigation so far.

*The Feed-Heating Limits.*—The cycle is now so clearly outlined that the examination of feed-heating effects is fairly straightforward. Further, the question is almost entirely one of range of heating and number of steps, and it is really hardly necessary to discuss any loss effects as influenced by these quantities.

The normal mode of calculation of the thermal efficiency in this case allows for the condensate from one heater passing to the next lower, so that the effect of this on net values is properly covered. The efficiency of the heaters should be so high as to make the influence of actual heat loss practically negligible. It would, on the whole, affect the range of heating rather than the number of stages, and the latter variable is the more important. There will be some temperature difference between the saturation temperature of steam and feed at any step; but this should cancel out in all the intermediate heaters and show finally as a failure of the feed to attain the saturation temperature of the steam at the first "tapping." This could be allowed for by assuming, say, 10 B.Th.U. difference; that is, the feed heat only gets to within 10 B.Th.U. of the liquid heat corresponding to the maximum "tap-off" pressure.

The extraction process, however, may be credited with the advantage of reducing the leaving loss of the turbine. In any comparison involving the non-feed heating cycle as a basis it might be necessary to allow for this. The allowance might be made by taking, say,

$$0{\cdot}05\,(\mathrm{H_A - H_B})$$

as the leaving loss under non-feed heating conditions, and this would then reduce to

$$0{\cdot}05\,(1-\Sigma x)\,(\mathrm{H_A - H_B})$$

when extraction effects were introduced.

The thermal efficiency, then, for any number of heaters covering the range up to the saturation temperature corresponding to the pressure at any such point as C on Fig. 9, is obtained from

$$\epsilon = \frac{(\mathrm{H_A - H_B})\{1-0{\cdot}05\,(1-\Sigma x)\} + \Sigma\,\mathrm{R\,H} - \Sigma\,x\,\mathrm{R\,H} - \Sigma\,x\,(\mathrm{H-H_B})}{\mathrm{H_A - h_c + \Sigma\,R\,H - \Sigma\,x\,.\,R\,H + 10}} \quad (13)$$

where the various symbols have the usual meanings, except that $\Sigma_x$ R H indicates the sum of the products obtained by multiplying any extraction quantity by the reheating totals that follow after the point of

* Paper read before the North-East Coast Institution of Engineers and Shipbuilders at Newcastle-upon-Tyne, on February 27, 1925.

extraction. This term, then, does not include any of the heaters on the final expansion curve.

With the smaller number of heaters, the efficiency rises to a maximum for a limited range of heating and then falls again as the range extends, but as the number increases the best range also grows until, with about 10 heaters, the best upper condition is at a pressure of 1,000 lb./in². Assuming that any specified number of heaters is used only at the best range for that number, we can reduce the results of the calculation to the very simple curve in Fig. 11. This curve shows how the efficiency increases beyond that for the non-feed heating cycle as the number of heaters are increased. In all cases the heaters have been assumed on equal heating steps. Unequal stepping has some slight influence with small numbers, such as two or three, but beyond that there is no effect.

It is seen that there is an increased gain with increased number throughout the whole range. Beyond the diagram the curve rises continuously towards a value of about 1·15 for an infinite number of heaters. There is, therefore, no clearly defined limit in this case. But there is a reasonable limit. The correct attitude would be that the limit should be fixed so that the benefits of the rapidly rising early part of the curve were obtained. Efficiency increases that can only be achieved at a very slow rate per added heater should be sacrificed. It is obvious that there must be a practical limit to the number; and it would seem most reasonable to fix it at that part of the curve where the form changes from a rapid to a slow rate of increase per heater.

This change in the curve lies in the region between 5 and 10. To use 5 at the best temperature value appropriate thereto would be to limit the feed-heating range rather much; whereas a number like 8 or upwards would practically be operating at the best conditions on the maximum range required. We may, therefore, choose 8 heaters operating on the range up to the saturation temperature corresponding to 1,000 lb./in² as the best limit deducible from the facts.

*The Limiting Cycle.*—We have, then, by progressive examination deduced the cycle that promises the best ultimate results when due consideration is given to all influences likely to affect the changes involved therein. This cycle starts from initial conditions of 900° F. 1,250 lb./in²., involves re-superheating at intermediate pressures of 500 lb. and 180 lb./in², and includes the employment of about eight extraction feed heaters, equally stepped, on a range of liquid heats up to that corresponding to 1,000 lb./in² pressure.

The temperature limit is an opinion expressed after examination of available information on materials. To many, impressed by present difficulties, it may appear high; but when dealing with ultimate limits, we are surely allowed to grant the possibility of advance, particularly in a line in which so much progress has been recorded in the recent past. But we have not ignored the extremely difficulty of this kind of advance, and it will be seen on examination that the limit mentioned is more a matter of consolidating present achievements than of great advance beyond them. Materials actually available are probably capable of use at 900° F. limits if other qualities apart from strength can be improved. There is room for difference of opinion in the matter, but we submit that the difference can hardly be extensive.

The processes of argument in connection with the steam operations have been strictly relative throughout. This must be emphasised. Specific loss allowances have, of course, entered into the calculations, but since each represents a stationary factor in the effect considered, errors in the assumption of such numerical values should only affect the relative figures to a very small degree. The real faults must lie in the mode of variation which has been deduced for the several influences and, of course, there is room for argument in this matter.

When we have derived a limiting cycle, we naturally ask what is the net performance on the basis so defined. This is, however, rather a large question and would really require another article. It would take us into the field of discussion wherein the possible improvements in boiler and turbine efficiencies and in condenser operations would require to pass under review. That would entail a complex and lengthy consideration; and yet we might admit that all of these conditions are so excellent, or so promising, at the moment that the room for improvement is really quite narrow. Thus with turbine efficiences approaching 85 per cent., boiler efficiencies rising towards 90 per cent. and condenser vacua quoted at 29½ in. for a 30-in. barometer, there would not appear to be much scope for spectacular advance in the main items.

It would seem, then, that in defining the limiting cycle we have established by far the largest part of the available margin of gain in the steam plant. We should, therefore, be able to obtain a useful idea of the limiting performance by direct analysis of the given cycle without recourse to the fuller discussion of possible improvements in detail efficiencies. In carrying out this final calculation merely as a matter of interest, we may be allowed to keep within the scope of this actual paper by dealing with the losses in the manner already established; that is, the result of this calculation may reflect any errors in the specific loss factors allowed rather than in the mode of variation thereof. But, on the whole, these may be considered rather in favour of the plant than otherwise, and hence we are really including a little for the possible improvements. In addition to the losses already considered as entering into the turbine, reheating and feed-heating processes, we may assume a 90 per cent. boiler efficiency, and a condenser vacuum, such as will allow an absolute pressure of 0·5 lb./in² at the turbine outlet.

On the basis of oil at 19,000 B.Th.U./lb., the net result is 0·495 lb. oil per kilowatt-hour, or 0·37 lb. per horse-power hour covering the transformation from oil to turbine power, but excluding auxiliaries. This, then, may be presented as the ultimate possible limit in the operation of high-power units under the best conditions in land plants.

Marine plants must operate well within any limits established by such method as have been used herein. In ship applications many other factors besides ultimate economy will control pressure and temperature advances. No doubt as land practice progresses, marine plants will likewise advance, but equal forward

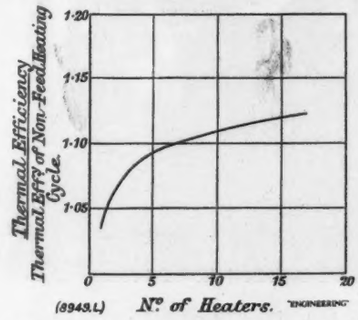



FIG. 11. INFLUENCE OF NUMBER OF FEED HEATERS.

steps need not be looked for. Thus, while a certain amount of extraction feed-heating is possible in a ship arrangement, the reheating difficulties are extreme, and it is very unlikely that such a process could be considered as applicable. This has been clearly pointed out by Sir Charles Parsons,* who gives an estimate of performance based on conditions of 5,000 h.p., 500 lb./in² 700 deg. F., with extraction feed heating but no reheating. His estimate is 0·57 lb. oil/s.h.p.-hour for turbines only. Messrs. Berg and Smith,† have also carried out an elaborate estimate of the result to be obtained by the application of modern steam-plant methods to ship installations. They are, however, concerned with a large plant of 50,000 h.p. with turbo-electric drive. Their conditions are 550 lb./in², 725 deg. F., and the final result shows 0·55 lb. oil/s.h.p.-hour for all purposes, which is about equivalent to 0·52 lb./s.h.p.-hour for turbines only.

Hence, although the marine plant cannot be expected to reach the limits ultimately open to the land plant, it seems easily possible to get enormous improvements by the adoption of similar methods.

The simple figures of consumption in this section are put forward merely as a matter of interest. The main function of the paper is to be taken as the discussion of the limits to the processes in the modern steam-plant cycle. The methods of examination are given in full, and the limits may be readily adjusted to suit different opinions, or the final performance developed to suit special knowledge of detail values. All calculations have been based on the Callendar equations, tables and diagrams, in so far as they require the explicit properties of steam and, of course, carry any degree of uncertainty therein involved.

LECTURES ON HYDRO-ELECTRIC MACHINERY.—A number of lantern slides of water turbines, Pelton wheels, pipe lines, and hydro-electric installations, prepared for the purpose of illustrating lectures, will be lent on request by Messrs. James Gordon and Co., Limited, engineers and contractors, of Windsor House, Kingsway, London, W.C.2.

* "The Steam Turbine," Parsons, International Mathematical Congress, Toronto, August, 1924. ENGINEERING, September 26, 1924.

† "Modern Tendencies in Steam Turbine Power Plants," Berg and Smith, *Mechanical Engineering*, October, 1924.

## PENINSULAR AND ORIENTAL LINER "RAZMAK."

HAVING completed satisfactory trials in Belfast Lough, the Peninsular and Oriental liner Razmak was handed over by the builders, Messrs. Harland and Wolff, on February 26. Intended for mail and passenger service between Aden and Bombay, the vessel has been built to the highest class of Lloyd's Register, and is 500 ft. long, 63 ft. broad, and 37 ft. 3 in. deep, while the gross tonnage is 10,600. Ten bulkheads divide the ship into watertight compartments, while the double bottom, extending completely fore and aft, is arranged for carrying water ballast.

The propelling machinery consists of two sets of quadruple expansion engines developing 12,000 i.h.p. Steam is generated in four double-ended and two single-ended boilers, working under Howden's system of forced draught, and fitted with Todd's oil-burning system. The latter will be supplied with fuel from the Persian fields. Each double-ended boiler has eight, and each single-ended boiler four large furnaces of the Morrison type. The working pressure is 215 lb. per square inch. All auxiliaries operate independently of the main engines. The electrical generating plant consists of three dynamos, each having an output of 150 kw. at a pressure of 220 volts. These sets are directly coupled to vertical double-acting enclosed engines, having forced lubrication. In addition a 25-kw. 220-volt dynamo, operated by an oil engine, is provided for emergency use. The wireless telegraph installation includes direction-finding equipment. Ventilation is by means of the punkah louvre system, which permits personal control and direction of a supply of fresh air in all staterooms, public rooms, and other parts of the ship. Four 38 brake horse-power forced-draught fans serve the boiler rooms, while six of 8 brake horse-power are installed for the engine room, all of which are electrically driven.

## WOOD PLANING AND DOVETAILING MACHINES.

THERE is at present a great demand for woodworking machinery for use in dealing with the production of floor boarding, mouldings and panels to meet the requirements of house builders and cabinet makers at small cost. For the cases in which a great output has to be produced, large and costly types of machines may be used, but in general the need is for a small compact and inexpensive equipment, which will serve all the requirements of an individual contractor. Such a machine made by Messrs. Haighs (Oldham) Limited, of Globe Iron Works, Oldham, is illustrated in Fig. 1 on page 368.

This machine is of the four cutter type and is capable of panel planing, thicknessing and moulding. Five standard sizes are manufactured which will plane from 12 in. width up to 30 in. width as a maximum and can deal with timber up to 6 in. thick in each case. The main frame, as will be observed from the illustration, is of substantial construction to eliminate possibility of vibrations when at work. The table is in two separate parts, the main one of which is arranged to rise and fall on wide adjustable slides by motion given by means of a handwheel through bevel gears and screws. In front of the bottom cutter head the other part of the table is provided and this can be made to rise and fall independently of the main table, so that the depth of cut may be varied at will. The bottom cutter head, which is made of special forged steel, is two-lipped and arranged at the one end for moulding cutters. A movable draw-out box is fitted to facilitate the sharpening and setting up of the cutters. The top one is of similar construction, except that for it there is no draw-out box, since it can be easily taken out of position. In both cases the spindles of the cutters revolve in large diameter ball bearings, to ensure that there is little loss of power in working. Roller bearings with ball thrusts at the foot serve for the vertical side spindles, and the whole arrangement is such that one of the spindles may be given a slight adjustment by a handle and screw, whilst the other may be similarly moved across the whole width of the machine. These side cutter blocks are of forged steel, two lipped and four-slotted and are usually made 4½ in. deep, while they may be made to rise and fall by screws on the end of the spindle.

For feeding purposes three top-rolls of large diameter are used, the first two of which are fluted but the back one is left plain to prevent marking of the finished work. Heavy machine cut gearing, roller chains and sprockets serve for the driving of these three rolls. To allow for variations in the thickness of the timber the middle roller can rise or fall ¾ in. This is made possible by having the gearing mounted on radius links so that the teeth of the wheels never get out of mesh, no matter in what position the roller is situated. There are also rollers set in the table, which act by

# WOOD PLANING AND DOVETAILING MACHINES.

CONSTRUCTED BY MESSRS. HAIGHS (OLDHAM), LIMITED, ENGINEERS, OLDHAM.

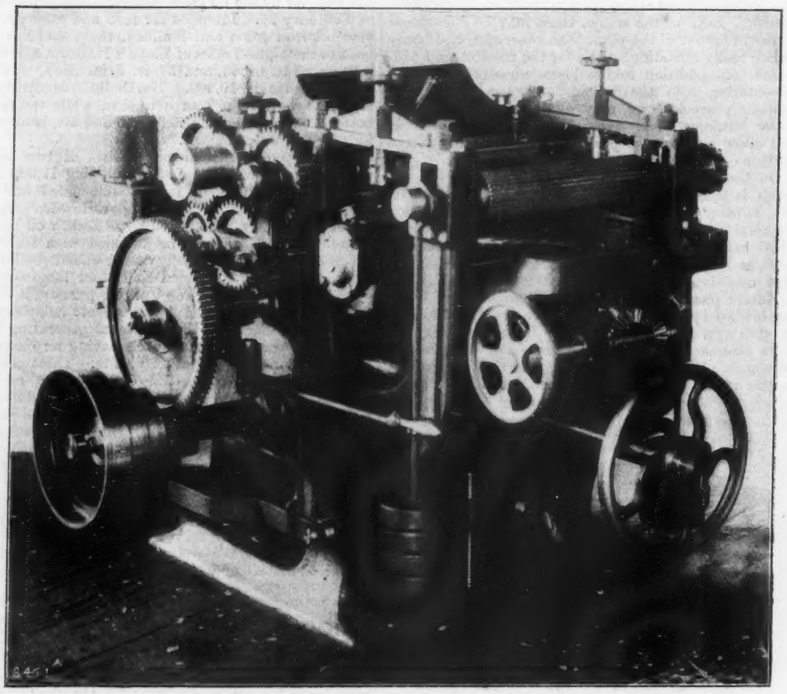


FIG. 1. PLANING, THICKNESSING AND MOULDING MACHINE.

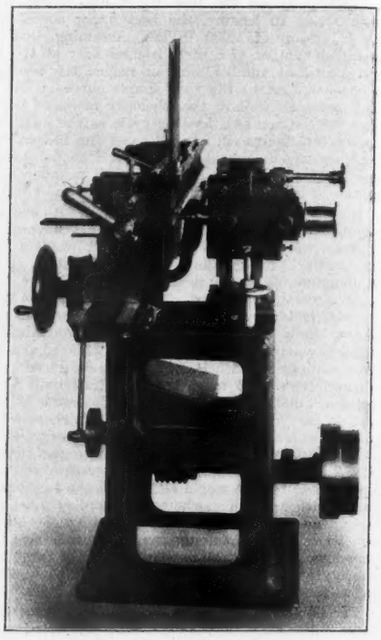


FIG. 2. DOVETAILING MACHINE.

simple friction only. Effective pressure arrangements are installed to hold down the work, those for the two front feed rolls being actuated by weights suspended from the ends of levers, while the others are of the spring type.

Another woodworking machine made by Messrs. Haighs (Oldham), Limited, is a semi-automatic dovetailing machine, which is illustrated in Fig. 2. This can be used to make either secret or open dovetails, and many hundreds of them are already in use. It can work with timber up to 24 in. width, with thicknesses of 1¼ in. for the ends of the boxes or ⅝ in. for the sides. The machine is a very serviceable one, since it can be used to cut both the mortice and tenon dovetail at the same operation, and the pitches at which the work is done can be varied at will. Usually the machine is arranged for pitches of ⅜ in., ½ in. and 1½ in., but it can be adjusted in 1/16 in. changes for other values. As it can be used for stop dovetails it marks an improvement on the machines previously supplied.

To hold the timber in position, two eccentric gripping clamps are provided, the one for the horizontal timber and the other for the vertical. From the shaft, which has a two-cone pulley, the motion is taken through a worm and worm wheel and a pair of bevels to the feed or crank discs. From these the requisite movement is obtained by the use of a connecting rod, the slide at the one end of which may be located at any position in the slot in these crank discs. The movement so obtained is made available for the feed by the use of machine-cut gearing associated with ratchets and pawls. For the cutter spindle a speed of about 10,000 r.p.m. is used, while it has both vertical and horizontal adjustments to suit the various pitches being worked. The machine is driven at a normal speed of 1,630 r.p.m. and when using 3 h.p. can turn out 32 complete dovetails per minute.

---

AIR MINISTRY COMPETITIONS FOR HELICOPTERS.—Owing to the fact that none of the entrants in the Air Ministry competition for flying machines of the helicopter type has so far submitted a machine for test, arrangements are being made for a second competition to terminate on April 30, 1926. Entries for the second competition must be received at the Air Ministry by April 30 next, and entrants for the original competition will be required to enter afresh for the second competition if they desire to compete. The prizes offered will be the same as before. Entry forms and full particulars of the conditions to be complied with can be obtained on application to the Secretary, Air Ministry, Adastral House, Kingsway, London, W.C. 2.

## THE INFLUENCE OF LEAD AND TIN ON THE BRITTLE RANGES OF BRASS.*

By D. BUNTING, M.Sc., PH.D.

OWING to the tendency to submit metals to increasingly rigorous conditions of temperature, and also to the fact that many brasses are worked and heat-treated at high temperatures, it is important that the various phenomena connected with the brittle ranges of brass should be investigated. In a former paper the author published the results of a research on the brittle ranges of brass,† and it was suggested that this investigation should be carried further; the present work is a continuation of the previous research. Commercial brasses often contain impurities, purposely added or otherwise, which may have a profound influence on the brittle range. The present work is an investigation of the effect of small percentages of two such impurities, lead and tin.

The apparatus employed for determining variations in brittleness was the Izod machine. This method of testing gave accurate and comparative results, and, moreover, could be adapted to high-temperature work. Full details of the apparatus, the method of performing tests, temperature control, &c., are given in the former paper.

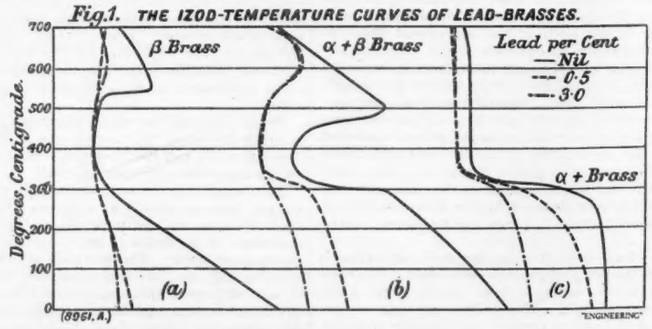
* Paper read before the Institute of Metals, London, on Wednesday, March 11, 1925. Abridged.

† ENGINEERING, vol. cxvii, page 350.

It was considered advisable to use the purest materials available, as the presence of a second impurity might have a pronounced effect. For this reason both electrolytic copper and electrolytic zinc were used for producing the alloys; the analyses and methods of producing the alloys are given in the previous paper. Assay lead (99·9 per cent.) and C.T.S. tin (99·94 per cent.) were added to the alloys as impurities.

The composition of all alloys was determined by the iodimetric estimation of the copper content. The lead or tin was estimated by the molybdate or stannic oxide methods respectively; the zinc being found by difference. Frequent complete analyses were made in order to check the purity of the alloys. A specimen analysis is given below.

*Fig. 1.* THE IZOD-TEMPERATURE CURVES OF LEAD-BRASSES.




| | Per cent. |
|---|---|
| Copper | 52·60 |
| Zinc (by difference) | 46·88 |
| Lead | 0·49 |
| Iron | 0·026 |
| Tin | Trace |
| Arsenic | Trace |

### PART I.

THE INFLUENCE OF SMALL PERCENTAGES OF LEAD ON THE BRITTLE RANGES OF BRASS.

It would appear from the results of other workers that lead is soluble to a very limited extent in either the $\alpha$ or $\beta$ solid solution of brass. This view is confirmed also in the author's experience, since, in the case of an $\alpha$ or $\beta$ brass containing 0·5 per cent. lead, the greater proportion of this metal exists as undissolved

# THE INFLUENCE OF LEAD AND TIN ON THE BRITTLE RANGES OF BRASS.

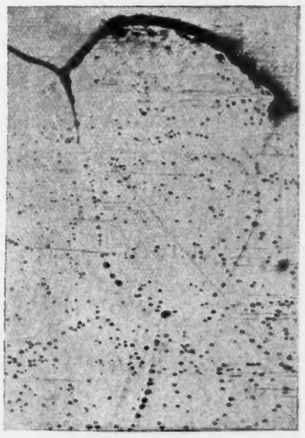


FIG. 2.
Alloy AP 1. Fractured 15 deg. C. Showing Lead Distribution. × 200.

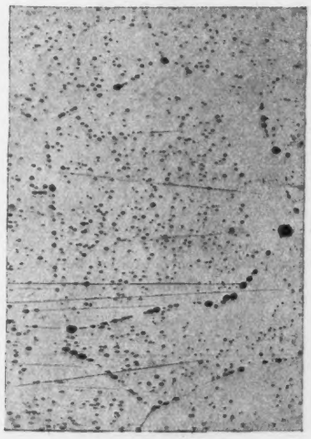


FIG. 3.
Alloy AP 3. Showing Lead Distribution. × 200.

FIG. 4.
Alloy EP 1. Intercrystalline Fracture at 400 deg. C. × 100.

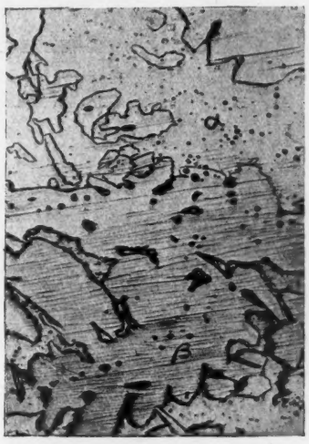


FIG. 5.
Alloy EP 3. Showing Distribution of Lead. × 200.

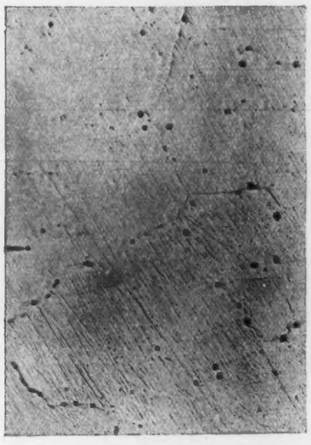


FIG. 6.
Alloy HP 1. Showing Distribution of Lead. × 200.

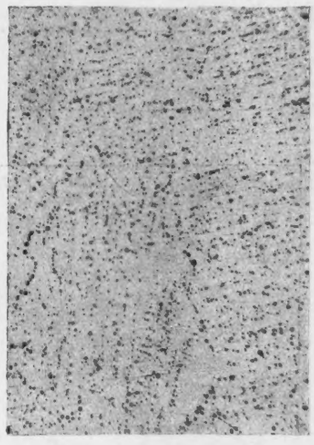


FIG. 7.
Alloy HP 3. Showing Distribution of Lead. × 50.

(REDUCED BY ONE-FIFTH IN REPRODUCTION.)

globules. Thus the solubility limit of an alloy of this description must be extremely small. To summarise: a minute percentage of lead is soluble in brass; if this limit is exceeded, the surplus will segregate as undissolved globules either to the crystal boundary or to the crystal interior. The influence on the mechanical properties is marked. Elongation, tensile strength, and impact strength are decreased considerably, whilst the machinability is greatly improved.

To ascertain the effect of lead on the brittle range a series of alloys was cast, the composition of which are given in Table I. In this table the actual analyses, and also the relative proportions of copper to zinc, ignoring the lead, are given.

TABLE I.—*Analyses of Alloys.*

| Alloy. | Chemical Analysis. | | | Proportion of Copper to Zinc. | | Constituents. |
|---|---|---|---|---|---|---|
| | Copper. Per cent. | Zinc. Per cent. | Lead. Per cent. | Copper. Per cent. | Zinc. Per cent. | |
| AP1 | 52·60 | 46·91 | 0·49 | 52·86 | 47·14 | $\beta$ + lead. |
| AP3 | 50·44 | 46·41 | 3·15 | 52·08 | 47·92 | $\beta$ + lead. |
| EP1 | 57·92 | 41·63 | 0·45 | 58·18 | 41·82 | $\alpha + \beta$ + lead. |
| EP3 | 56·70 | 40·26 | 3·04 | 58·48 | 41·52 | $\alpha + \beta$ + lead. |
| HP1 | 64·46 | 35·07 | 0·47 | 64·76 | 35·24 | $\alpha$ + lead. |
| HP3 | 63·69 | 33·46 | 2·85 | 65·56 | 34·44 | $\alpha$ + lead. |

Impact tests were performed on these alloys at temperatures rising by intervals of 50 deg. C. from room temperature to 700 deg. C. The results of the tests are given in Fig. 1. On the completion of each test an Izod-temperature curve was plotted, showing the variation in brittleness of each alloy at various temperatures. These curves are shown in Fig. 1. In order to illustrate the effect of increasing amounts of lead on the brittle range of these brasses, the Izod curves of each alloy, containing 0·5 per cent. and 3 per cent. of lead, were plotted together with the Izod curve of a pure brass of similar composition on the same zero, thus giving a comparison between the three curves and showing any variation in the impact figure due to progressive increases of lead.

To aid in the correct interpretation of these results micro-examination of certain fractured specimens was performed, the procedure being similar to that followed in the previous work on pure brass.

*The Influence of Lead on $\beta$ Brass (52 per cent. Copper).* The effect of adding a small amount of lead to $\beta$ brass is to cause extreme brittleness at all temperatures, on account of globules of the impurity segregating to the crystal boundary. Progressive increases in the lead percentage have no further effect, as no alteration occurs in the amount of lead segregated to the crystal boundary (see Fig. 1 (*a*) and Figs. 2 and 3).

*The Influence of Lead on $\alpha + \beta$ Brass (58 per cent. Copper).*—The presence of lead in $\alpha + \beta$ brass causes an increase in brittleness, proportional to the percentage of lead present, at all temperatures below the brittle range. This is due to the fact that no lead is present on the crystal boundary, and so intercrystalline weakness is not produced. Within the range, a small addition of lead lowers the impact strength considerably, but further additions have little effect. In the recovery area lead has no influence, owing to the great plasticity of the brass at these temperatures (see Fig. 1 (*b*) and Figs. 4 and 5).

*The Influence of Lead on a Brass (65 per cent. Copper).* The effect of lead on the $\alpha$ alloys is to cause a decrease in the impact strength, proportional to the amount of lead present, at temperatures below the brittle range. Within the range, the Izod figure is lowered slightly by a very small addition of lead, but progressive increases have no further effect. The lead was found to segregate as globules to the crystal boundary, but no failure of intercrystalline cohesion followed, as in the case of $\beta$ brass (see Fig. 1 (*c*) and Figs. 6 and 7).

### *Summary.*

The conclusions drawn from these results are:—

1. Lead in solution causes a slight but uniform decrease in the impact strength, and does not affect the limits of the brittle range appreciably.

2. Lead present as a mechanical mixture has no apparent effect on the impact strength in the brittle range, but at all temperatures, above and below, brittleness results.

3. The presence of lead in brass is to be avoided in connection with apparatus working at high temperatures, such as occur in high-pressure turbines, &c.; but for the usual hot-stamping work no harmful results will ensue, provided the temperature of working be kept sufficiently high, and that the finished articles are not called upon to resist shock stresses.

## PART II.

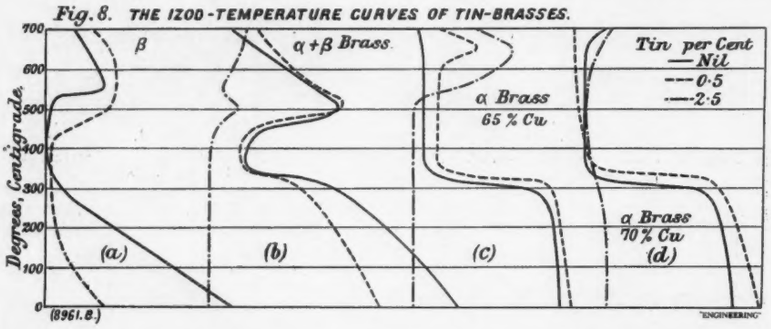
### THE INFLUENCE OF SMALL PERCENTAGES OF TIN ON THE BRITTLE RANGES OF BRASS.

The effect of tin on the constitution and microstructure of brass has been investigated by many workers, and the results obtained can be summarised in

the researches of Hudson on this subject. It is impossible to give an adequate summary of this work in the space at disposal, but briefly it may be stated that the $a$, $a + \beta$, and $\beta$ solutions of brass all dissolve a certain amount of tin, varying from 2 per cent. to 0·5 per cent., according to composition. Any tin in excess of the solubility limit produces a brittle blue constituent known as $\delta$ when occurring in $a$ or $a + \beta$ brass, and $\gamma$ when present in $\beta$ brass. The effect of tin in solution is to shift the constitution towards the zinc end of the diagram, owing to its being equivalent to the addition of a certain amount of zinc. The zinc equivalent is given by Guillet as 2.

As regards the mechanical and physical properties, it is stated that the addition of tin within the solubility limit raises the yield point and the ultimate strength, but lowers the elongation. If sufficient tin be present to produce $\gamma$ or $\delta$, the tensile strength may be improved, depending on the amount of $\gamma$ or $\delta$ present, but the elongation and impact strength will be reduced considerably.

*Fig. 8.* THE IZOD-TEMPERATURE CURVES OF TIN-BRASSES.




of intercrystalline cohesion; this causes the brittle range to be extended by 160 deg. C. If the solubility limit be exceeded the $\gamma$ constituent is produced, and and extremely brittle alloy results (see Fig. 8 (*a*)).

*The Influence of Tin on $a + \beta$ Brass (58 per cent. Copper).*—The effect of tin in solution on the $a + \beta$ alloys is to decrease the impact strength at low temperatures. The brittle range is unaffected, whilst the recovery area is slightly increased, due to greater crystal rigidity. The effect of tin in excess of the solubility limit is to cause pronounced intercrystalline brittleness throughout the temperature range of testing; this is due to the excess tin producing the brittle $\delta$ constituent as an envelope around each crystal grain. A slight recovery of impact strength takes place at 470 deg. C., due to solution of the $\delta$ in $\beta$, and an inversion occurs in the curve at 520 deg. C., corresponding with the inversion of the copper-tin $\beta$ into the $a + \delta$ eutectoid (see Fig. 8 (*b*) and Figs. 9 and 10).

*The Influence of Tin on a Brass (65 per cent. Copper).*—The effect of tin in solution on $a$ brass (65 per cent. copper) is to increase the impact strength at all temperatures, and so to decrease the brittle range; whilst a slight recovery of intercrystalline cohesion occurs at high temperatures. The effect of tin in excess of the solubility limit is to cause extreme brittleness, due to the production of $\delta$, at all temperatures below 500 deg. C. Above this point the absorption of $\delta$ by $\beta$ occurs, and recovery of intercrystalline cohesion results (see Fig. 8 (*c*) and Fig. 11).

*The Influence of Tin on a Brass (70 per cent. Copper).*—The effect of tin in solution on $a$ brass (70 per cent. copper) is to increase the impact strength at low temperatures.

The lower limit of the range is raised slightly, but the upper limit is absent, so increasing the range at high temperatures. The effect of tin in excess of the solubility limit is to produce an alloy which is extremely brittle at all temperatures, owing to the presence of $\delta$ at the crystal boundary (see Fig. 8 (*d*) and Fig. 12).

FIG. 9.

Alloy ET 1. Intracrystalline Fracture at 15 deg. C. × 50.

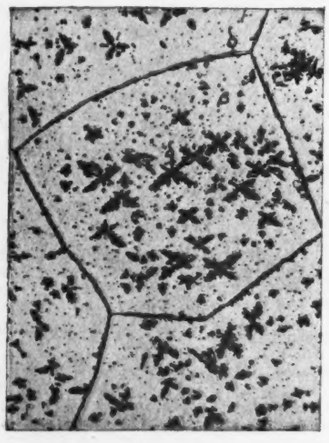


FIG. 10.

Alloy ET 3. Showing $\delta$ on Grain Boundary and in $\beta$ Matrix. × 75.

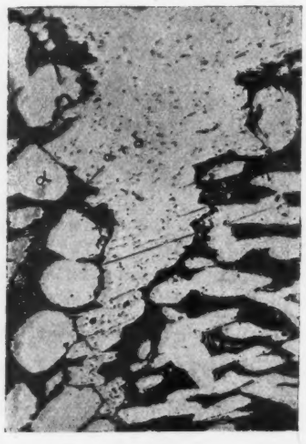


FIG. 11.

Alloy HT 3. Intercrystalline Fracture at 600 deg. C. Showing Fracture passing through $a + \delta$ Eutectoid. × 200.

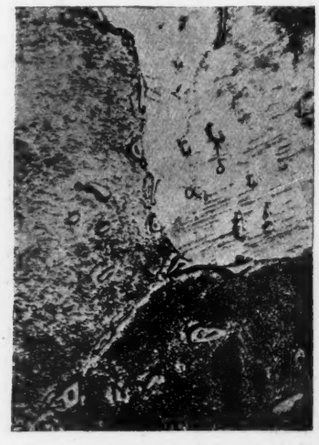


FIG. 12.

Alloy JT 3. Showing $\delta$ on Boundaries of $a$ Crystals. × 250.

(REDUCED BY ONE-FIFTH IN REPRODUCTION.)

In order to ascertain the effect of tin on the brittle ranges a series of alloys was cast, the composition of which is shown in Table II. In this table three sets of proportional figures are given. These show the following :—

1. The actual percentages of copper, zinc, and tin.
2. The relative proportions of copper to zinc, ignoring the tin.
3. The relative proportions of copper and zinc, taking the tin into consideration, according to Guillet's zinc equivalent.

Impact tests were performed on these alloys as before. The details of the tests are given in Fig. 8. On the completion of these tests, Izod-temperature curves were plotted by the method employed in the previous investigation on the effect of lead. These curves given in Fig. 8 show the effect of increasing percentages of tin on the impact strength.

TABLE II.—*Analyses of Alloys.*

| Alloy. | Chemical Analysis. | | | Proportion of Copper to Zinc, ignoring Tin. | | Proportion of Copper to Zinc + Tin. | | Constituents. |
|---|---|---|---|---|---|---|---|---|
| | Copper. Per cent. | Zinc. Per cent. | Tin. Per cent. | Copper. Per cent. | Zinc. Per cent. | Copper. Per cent. | Zinc. Per cent. | |
| AT1 | 53·08 | 46·52 | 0·40 | 53·29 | 46·71 | 52·87 | 47·13 | $\delta$ |
| ET1 | 57·90 | 41·55 | 0·55 | 58·22 | 41·78 | 57·58 | 42·42 | $a + \beta$ |
| ET3 | 56·16 | 41·19 | 2·65 | 57·68 | 42·32 | 54·71 | 45·29 | $a + \beta + \delta$ |
| HT1 | 64·76 | 34·80 | 0·44 | 65·05 | 34·95 | 64·47 | 35·53 | $a$ |
| HT3 | 63·12 | 34·37 | 2·51 | 64·74 | 35·26 | 61·57 | 38·43 | $a + \delta$ |
| JT1 | 68·40 | 31·14 | 0·46 | 68·72 | 31·28 | 68·09 | 31·91 | $a$ |
| JT3 | 67·62 | 29·72 | 2·66 | 69·47 | 30·53 | 65·87 | 34·13 | $a + \delta$ |

*Summary.*

The conclusions drawn from these results are :—

1. The percentage of tin must not exceed the solubility limit, as extreme brittleness results.
2. Tin in solution has a harmful effect on $\beta$ brass, or $a + \beta$ brass ($\beta$ matrix), causing increased brittleness.
3. Tin in solution in $a$ brass or $a + \beta$ brass ($a$ matrix), improves the impact strength and decreases the brittle range, provided that the zinc equivalent does not shift the constitution into an area of lower impact strength.
4. The addition of tin has a beneficial effect on the $a$ brasses, and the $a + \beta$ brasses containing from 65 per cent. to 60 per cent. copper.

This research was carried out in the Metallurgical Department of the University of Birmingham, under the direction of Professor T. Turner, M.Sc., A.R.S.M.